100

General

101 INTRODUCTION

These specifications shall apply to all such road and bridge works as are required to be executed under the Contract or otherwise directed by the Engineer-in-Charge (hereinafter referred to as the Engineer). In every case, the work shall be carried out to the satisfaction of the Engineer and conform to the location, lines, dimensions, grades and cross-sections shown on the drawings or as indicated by the Engineer. The quality of materials, processing of materials as may be needed at the site, salient features of the construction work and quality of finished work, measures for safety of workers and public and traffic arrangements during execution shall comply with the requirements set forth in succeeding sections. Where the drawings and Specifications describe a portion of the work in only general terms, and not in complete detail, it shall be understood that only the sound engineering practice is to prevail, materials and workmanship of the best quality are to be employed and the instructions of the Engineer are to be fully complied with.

A list of Indian Roads Congress Specifications and Recommended Codes of Practice which have been made use of in the preparation of these Specifications is given at *Appendix-1.* The latest edition of all Specifications/Standards till 30 (thirty) days before the final date of submission of the tender, shall be adopted.

102 DEFINITIONS

The words like Contract, Contractor, Engineer (synonymous with Engineer-in-Charge), Drawings, Employer, Government, Works and Work Site used in these Specifications shall be considered to have the meaning as understood from the definitions of these terms given in the General Conditions of Contract.

AASHTO	:	American Association of State Highway and Transportation Officials
ASTM	:	American Society for Testing and Materials
BS	:	British Standard published by the British Standards Institution
BIS	:	Bureau of Indian Standards
BOQ	:	Bill of Quantities
CBR	:	California Bearing Ratio
IRC	:	Indian Roads Congress
IS	:	Indian Standard published by the Bureau of Indian Standards
QA	:	Quality Assurance

The various elements in the cross-section of a road referred to in these Specifications are shown in the cross-sections in Fig. 100-1 and 100-2.

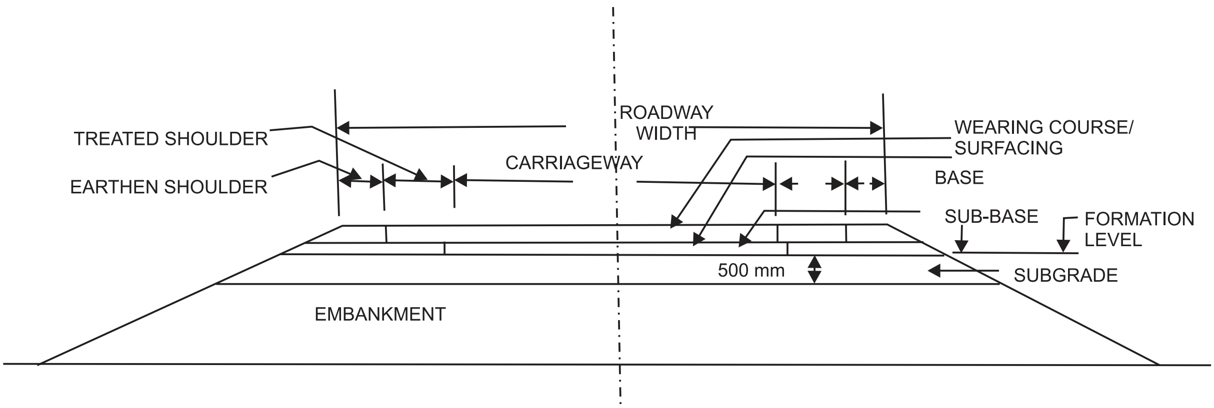

Fig. 100.1 Terms Used in the Specifications to Describe Road Cross-Section Elements with a Flexible Pavement

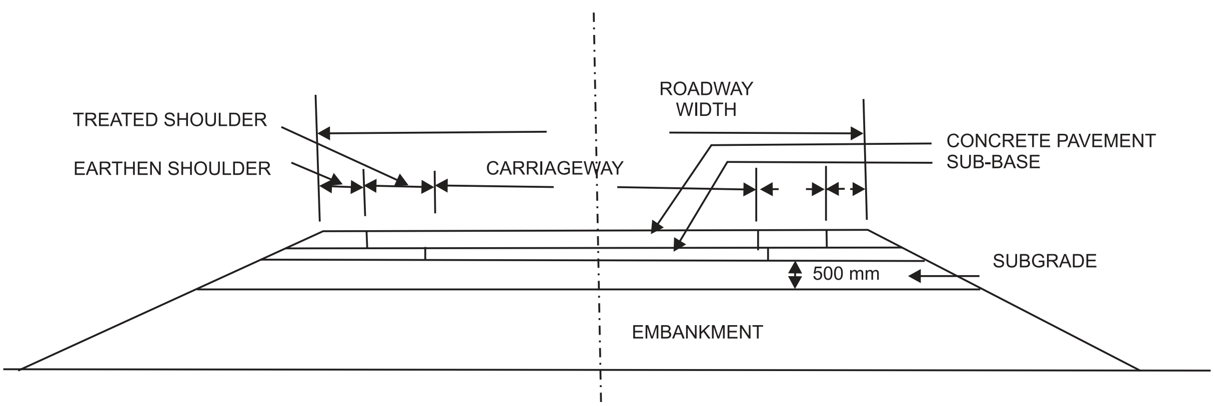

Fig. 100.2 Terms Used in the Specifications to Describe Road Cross-Section Elements with a Concrete Pavement

Treated shoulders shown in the cross-section shall be of two types:-

i) “Hard” shoulders which have select gravel/moorum, any other compacted granular layer or bricks.

ii) “Paved” shoulders which have a bituminous surfacing over granular layers.

103 MATERIALS AND TEST STANDARDS

The relevant standards for materials, as well as the testing procedures, have been indicated at appropriate places in the specifications. A list of these standards with their full title and the year of publication applicable are included at Appendix – 2.

104 SIEVE DESIGNATIONS

The sieve designations referred to in the Specifications correspond to those specified by Bureau of Indian Standards in IS:460. Table 100-1 gives the list of the commonly used IS sieves.

Table 100-1 Designation of Test Sieves

IS Designation Conforming to IS:460

(in mm)	(in micron)
*125	850
106	
* 90	* 710
75	600
* 63	* 500
53	425
	355
	300
* 45	* 250
37.5	212
* 31.5	* 180
26.5	150
* 22.4	* 125
19.0	106
* 16.0	* 90
13.2	74
* 11.2	* 63
9.50	53
* 8.00	* 45
6.70	
* 5.60	
4.75	

(in mm)	(in micron)
* 4.00	
3.35	
* 2.80	
2.36	
* 2.00	
1.70	
* 1.40	
1.18	
* 1.00	

Notes: 1) '*' are the principal sizes stated in ISO-565
2) Sieve sizes given in BS:410 & ASTM–E 11 are same as in IS:460
3) Only sieves with square openings shall be used.

105 SCOPE OF WORK

105.1 The work to be carried out under the Contract shall consist of the various items as generally described in the Tender Documents as well as in the Bill of Quantities furnished in the Tender Documents.

105.2 The works to be performed shall also include all general works preparatory to the construction of roads, bridges, canal crossings, drainage and all other related works. The works shall include work of any kind necessary for the due and satisfactory construction, completion and maintenance of works to the intent and meaning of the drawings and these Specifications and further drawings and orders that may be issued by the Engineer from time to time. The scope of work shall include compliance by the Contractor with all Conditions of Contract, whether specifically mentioned or not in the various Sections of these Specifications, all materials, apparatus, plant, equipment, tools, fuel, water, strutting, timbering, transport, offices, stores, workshop, staff, labour and the provision of proper and sufficient protective works, diversions, temporary fencing and lighting. It shall also include, safety of public workers, first-aid equipment, suitable accommodation for the staff and workmen with adequate sanitary arrangements, the effecting and maintenance of all insurances, the payment of all wages, salaries, fees, royalties, duties or other charges arising out of the erection of works and the regular clearance of rubbish, reinstatement and clearing-up of the site as may be required on completion of works, safety of the public and protection of the works and adjoining land.

105.3 The Contractor shall ensure that all actions are taken to build in quality assurance in the planning, management and execution of works. The quality assurance shall cover all states of work such as setting out, selection of materials, selection of construction methods, selection of equipment and plant, deployment of personnel and supervisory staff, quality control testing, etc. The QA programme shall cover the details as per IRC:SP:47 and IRC:SP:57. These shall broadly cover quality assurance aspects of all services rendered, all items to be supplied and all activities to be performed under the contract including temporary structures and equipments which will influence the quality of the completed works or the progress of the contract.

As a minimum, it shall cover the following :

i) Organisation and management responsibility,
ii) Document and data control,
iii) Construction programme,
iv) Methods statements,
v) Process control,
vi) Working, inspection, testing and documentary procedures,
vii) Arrangement for traffic during construction and maintenance,
viii) Control and documentation of purchasing and handling of materials,
ix) Non-conformity and corrective actions,
x) Internal quality audit,
xi) Servicing,
xii) Training of staff,
xiii) Site environmental plan

The general procedures of the QA programme shall be submitted to the Engineer for approval, not later than 28 days after the date of letter of acceptance. The special part of the QA programme shall be submitted successively to the effect that it shall have been approved prior to the commencement of the activities to which the programme shall apply. The work of building in quality assurance shall be deemed to be covered in the scope of the work.

105.4 The Contractor shall furnish, at least 7 days in advance unless otherwise stipulated in the contract his programme of commencement of item of work, the method of working he intends to adopt for various items of work such as site clearance, construction for embankment, sub-base, base, surfacing, culverts, bridges, retaining walls, well-sinking, cast-in-situ piling, construction of cast-in-situ pre-stressed concrete superstructure, and such other items for which the Engineer demands the submission of the method of working. He shall provide information regarding the details of the method of working and equipment he proposes to employ and satisfy the Engineer about the adequacy and safety of the same. The sole responsibility for the safety and adequacy of the methods adopted by the Contractor will, however, rest on the Contractor, irrespective of any approval given by the Engineer.

106. CONSTRUCTION EQUIPMENT

In addition to the conditions indicated in the Contract Documents, the following conditions regarding use of equipment in works shall be satisfied:

a) The Contractor shall be required to give a trial run of the equipment for establishing their capability to achieve the laid down Specifications and tolerances to the satisfaction of the Engineer before commencement of the work;

b) All equipment provided shall be of proven efficiency and shall be operated and maintained at all times in a manner acceptable to the Engineer;

c) Plants, equipments and instruments provided shall have adequate sensitivity, facility for calibration to desired level and shall be robust;

d) Plants, equipments and instruments provided shall have data logging arrangement and control systems to enable automatic feedback control of process;

e) Plants, equipments and instruments provided shall have adequate safety features and pollution control devices;

f) Plants equipments and instruments provided shall be operated by skilled and qualified operators;

g) All the plant/equipment to be deployed on the works shall be got approved from the Engineer for ensuring their fitness and efficiency before commencement of work;

h) Any material or equipment not meeting the approval of the Engineer shall be removed from the site forthwith;

i) No equipment shall be removed from site without permission of the Engineer;

j) The Contractor shall also make available stand by equipments and spare parts; and

k) The Contractor shall also make available equipments for site quality control work as directed by the Engineer.

107 CONTRACT DRAWINGS

107.1 The Contract Drawings provided for tendering purposes shall be as contained in the Tender Documents and shall be used as reference only. The Contractor should visualize the nature and type of work contemplated and to ensure that the rates and prices quoted by him in the Bill of Quantities have due consideration of the site and complexities of work involved during actual execution/construction.

107.2 The Contractor based on hs surveys and investigations, shall submit the working drawings (hard/soft copy) to the Engineer for each activity atleast 45 days in advance of the scheduled date to the start of the activity as per his aproved work programme. The working drawings shall clearly show the modifications, if any, proposed with reference to corresponding tender drawings. The Engineer shall review the working drawings including the modifications proposed, if any, revise the drawings, if required, approve and issue to the Contractor two copies of Good for Construction (GFC) drawings atleast 21 days in advance of the scheduled date of the start of the activity.

107.3 After careful study of GFC drawings, the Contractor shall prepare all supplementary and working drawings and shall submit the same to the Engineer for approval 7 days prior to schedule date for execution of the works unless otherwise stipulated in the Contract.

107.4 Examination and/or approval by the Engineer of any drawings or other documents submitted by the Contractor shall not relieve the Contractor of his responsibilities or liabilities under the Contract.

107.5 The tendered rates/prices for the work shall be deemed to include the cost of preparation, supply and delivery of all necessary drawings, prints, tracings and negatives which the Contractor is required to provide in accordance with the Contract.

108 SITE INFORMATION

108.1 The information about the site of work and site conditions in the Tender Documents is given in good faith for guidance only but the Contractor shall satisfy himself regarding all aspects of site conditions.

108.2 The location of the works and the general site particulars are as shown in the Site plan/Index plan enclosed with the Tender Documents.

108.3 Whereas the right-of-way to the bridge sites/road works shall be provided to the Contractor by the Engineer, the Contractor shall have to make his own arrangement for the land required by him for site offices, field laboratory, site for plants and equipments, labour camps, stores, etc.

109. SETTING OUT

109.1 The Contractor shall establish working Bench Marks tied with the Reference Bench Mark in the area soon after taking possession of the site. The Reference Bench Mark for the area shall be as indicated in the Contract Documents and the values of the same shall be obtained by the Contractor from the Engineer. The working Bench Marks shall be at the rate of four per km and also at or near all drainage structures, over-bridges and underpasses. The working Bench Marks/levels should be got approved from the Engineer. Checks must be made on these Bench Marks once every month and adjustments, if any, got agreed with the Engineer and recorded. An up-to-date record of all Bench Marks including approved adjustments, if any, shall be maintained by the Contractor and also a copy supplied to the Engineer for his record.

109.2 The lines and levels of formation, side slopes, drainage works, carriageways and shoulders shall be carefully set out and frequently checked, care being taken to ensure that correct gradients and cross-sections are obtained everywhere.

109.3 In order to facilitate the setting out of the works, the center line of the carriageway or highway must be accurately established by the Contractor and approved by the Engineer. It must then be accurately referenced in a manner satisfactory to the Engineer, every 50 m intervals in plain and rolling terrains and 20 m intervals in hilly terrain and in all curve points as directed by the Engineer, with marker pegs and chainage boards set in or near the fence line, and a schedule of reference dimensions shall be prepared and supplied by the Contractor to the Engineer. These markers shall be maintained until the works reach finished formation level and are accepted by the Engineer.

109.4 On construction reaching the formation level stage, the center line shall again be set out by the Contractor and when approved by the Engineer, shall be accurately referenced in a manner satisfactory to the Engineer by marker pegs set at the outer limits of the formation.

109.5 No reference peg or marker shall be moved or withdrawn without the approval of the Engineer and no earthwork or structural work shall be commenced until the center line has been referenced.

109.6 The Contractor will be the sole responsible party for safe-guarding all survey monuments, bench marks, beacons, etc. The Engineer will provide the Contractor with the data necessary for setting out the center line. All dimensions and levels shown on the drawings or mentioned in documents forming part of or issued under the Contract shall be verified by the Contractor on the site and he shall immediately inform the Engineer of any apparent errors or discrepancies in such dimensions of levels. The Contractor shall, in connection with the staking out of the center line, survey the terrain along the road and shall submit to the Engineer for his approval, a profile along the road center line and cross-sections at intervals as required by the Engineer.

109.7 After obtaining approval of the Engineer, work on earthwork can commence and the profile and cross-sections as per Section 305, shall form the basis for measurements and payment. The Contractor shall be responsible for ensuring that all the basic traverse points are in place at the commencement of the contract and, if any, are missing, or appear to have been disturbed, the Contractor shall make arrangements to re-establish these points. A "Survey File" containing the necessary data will be made available for this purpose. If in the opinion of the Engineer, design modifications of the center line or grade are advisable, the Engineer will issue detailed instructions to the Contractor and the Contractor shall perform the modifications in the field, as required, and modify the ground levels on the cross-sections accordingly as many times as required. There will be no separate payment for any survey work performed by the Contractor. The cost of these services shall be considered as being included in the rate of the items of work in the Bill of Quantities.

109.8 The work of setting out shall be deemed to be a part of general works preparatory to the execution of work and no separate payment shall be made for the same.

109.9 Precision automatic levels, having a standard deviation of ± 2 mm per km, and fitted with micrometer attachment shall be used for all double run levelling work. Setting out of the road alignment and measurement of angles shall be done by using theodolite with traversing target, having an accuracy of one second. Measurement of distances shall be done preferably using precision instruments like Distomat.

110 PUBLIC UTILITIES

110.1 Drawings scheduling the affected services like water pipes, sewers, oil pipelines, cables, gas ducts etc. owned by various authorities including Public Undertakings and Local Authorities included in the Contract Documents shall be verified by the Contractor for the accuracy of the information prior to the commencement of any work.

110.2 Notwithstanding the fact that the information on affected services may not be exhaustive, the final position of these services within the works shall be supposed to have been indicated based on the information furnished by different bodies and to the extent the bodies are familiar with the final proposals. The intermediate stages of the works are, however, unknown at the design stage, these being dictated by the Contractor's methods of working. Accordingly, the Contractor's programme must take into account the period of notice and duration of diversionary works of each body as given on the Drawings and the Contractor must also allow for any effect of these services and alterations upon the Works and for arranging regular meetings with the various bodies at the commencement of the Contract and throughout the period of the Works, the Contractor shall have no objection if the public utility bodies vary their decisions in the execution of their proposals in terms of programme and construction, provided that, in the opinion of the Engineer, the Contractor has received reasonable notice thereof before the relevant alterations are put in hand.

110.3 No clearance or alterations to the utility shall be carried out unless specially ordered by the Engineer.

110.4 Any services affected by the Works must be temporarily supported by the Contractor who must also take all measures reasonably required by the various bodies to protect their services and property during the progress of the Works.

110.5 The Contractor may be required to carry out certain works for and on behalf of the various bodies and he shall also provide, with the prior approval of the Engineer, such assistance to the various bodies as may be authorized by the Engineer.

110.6 The work of temporarily supporting and protecting the public utility services during execution of the Works shall be deemed to be part of the Contract and not extra payment shall be made for the same.

110.7 The Contractor shall be responsible to co-ordinate with the service providers for cutting of trees, shifting of utilities, removal of encroachments etc. to make site unencumbered for completion of work. This will include frequent follow-up meetings. Co-ordination for making project site unencumbered shall be deemed to be part of the Contract and no extra payment shall be made for the same.

110.8 In some cases, the Contractor may be required to carry out the removal or shifting of certain services/utilities on specific orders from the Engineer for which payment shall be made to him. Such works, however, shall be taken up by the Contractor only after obtaining clearance from the Engineer and ensuring adequate safety measures.

111 PRECAUTIONS FOR SAFEGUARDING THE ENVIRONMENT

111.1 General

The Contractor shall take all precautions for safeguarding the environment during the course of the construction of the works. He shall abide by all laws, rules and regulations in force governing pollution and environmental protection that are applicable in the area where the works are situated.

111.2 Borrow pits for Embankment Construction

Borrow pits shall not be dug in the right-of-way of the road. The stipulations in Section 305.2.2 and guidelines provided in IRC 10 shall govern. The Contractor shall seek prior approval from the concerned authorities for operating the borrow pits.

111.3 Quarry Operations

The Contractor shall obtain materials from quarries only after obtaining the consent of the Mining Department or other concerned authorities. The quarry operations shall be undertaken within the purview of the rules and regulations in force.

111.4 Control of Soil Erosion, Sedimentation and Water Pollution

The Contractor shall carry out the works in such a manner that soil erosion is fully controlled, and sedimentation and pollution of natural water courses, ponds, tanks and reservoirs is avoided. The stipulations in Clause 306 shall govern.

111.5 Pollution from Plants and Batching Plants

Stone crushing and screening plants, Bituminous hot-mix plants, concrete batching plants etc. shall be located sufficiently away from habitation, agricultural operations or industrial establishments. The Contractor shall take every precaution to reduce the levels of noise, vibration, dust and emissions from his plants and shall be fully responsible for any claims or damages caused to the owners of property, fields and residences in the vicinity and violation of pollution control norms, if any.

111.6 Substances Hazardous to Health

The Contractor shall not use or generate any materials in the works which are hazardous to the health of persons, animals or vegetation. Where it is necessary to use some substances which can cause injury to the health of workers, the Contractor shall provide protective clothing or appliances to his workers.

111.7 Use of Nuclear Gauges

Nuclear gauges shall be used only where permitted by the Engineer. The Contractor shall provide the Engineer with a copy of the regulations governing the safe use of nuclear gauges he intends to employ and shall abide by such regulations.

111.8 The Contractor must take all reasonable steps to minimize dust nuisance during the construction of the works along the haul roads and the worksites by sprinkling water at a frequency specified by the Engineer.

All existing highways and roads used by vehicles or equipments of the Contractor or any of his sub-contractors or suppliers of materials or plant, and similarly any new roads which are part of the works and which are being used by traffic, shall be kept clean and clear of all dust/mud or other extraneous materials dropped by the said vehicles. Similarly, all dust/mud or other extraneous materials from the works spreading on these highways shall be immediately cleared by the Contractor.

Clearance shall be effected immediately by sweeping and removal of debris, and all dust, mud and other debris shall be removed entirely from the road surface. Additionally, if so directed by the Engineer, the road surface shall be hosed or watered using suitable equipment.

Any structural damage and loss of riding surface caused to the existing roads by the Contractor's construction vehicles/ equipment shall be made good without any extra cost.

Compliance with the foregoing will not relieve the Contractor of any responsibility for complying with the requirements of any authority in respect of the roads used by him.

111.9 Occupational Health & Safety of the workforce

The Contractor shall prepare and submit to the Engineer the Occupational Health & Safety Procedures / Practices for the workforce in all quarry sites, plant sites, work sites, camp sites, etc., in accordance with the applicable laws.

111.10 Water Sources and Water Quality

The Contractor shall provide independent sources of water supply, such as bore wells, for use in the Works and for associated storage, workshop and work force compounds. Prior approval shall be obtained from the relevant State Authorities and all installations shall be in compliance with local regulations.

The Contractor shall protect all watercourses, waterways, ditches, canals, drains, lakes and the like from pollution as a result of the execution of the Works. All water and other liquid waste products arising on the Site shall be collected and disposed of at a location on or off the Site and in a manner that shall not be cause either nuisance or pollution.

The Contractor shall at all times ensure that all existing stream courses and drains within and adjacent to the Site are kept safe and free from any debris and any materials arising from the Works. The Contractor shall not discharge or deposit any matter arising from the execution of the Works into any water course except with the permission of the Engineer and the regulatory authority concerned.

111.11 Air Quality

The Contractor shall device and implement methods of working to minimize dust, gaseous and other air-borne emissions and carry out the Works in such a manner as to minimize adverse impacts on the air quality. Construction camps shall have facilities for LPG fuel. The use of firewood shall not be permitted.

The Contractor shall utilize effective water sprays during delivery, manufacture, processing

and handling of materials when dust is likely to be created, and to dampen stored materials during dry and windy weather. Stockpiles of friable materials shall be covered with clean tarpaulins, with applications of sprayed water during dry and windy weather. Stockpiles of materials or debris shall be dampened prior to their movement, except where this is contrary to the Specification.

Any vehicle with open load-carrying area used for transporting potentially dust-producing material shall have properly fitting side and tail boards. Materials having the potential to produce dust shall not be loaded to a level higher than the side and tail boards and shall be covered with clean tarpaulins in good condition. The tarpaulin shall be properly secured and extend at least 300mm over the edges of the side and tail boards.

111.12 Construction Camps

The construction camps shall conform to the State and National building regulations as applicable. The area for the storage of polluted materials shall be stored on impervious floors and shall be surrounded by impervious ditches in order to avoid spilling of polluted material to surrounding areas.

Construction camps shall be properly arranged to avoid noise pollution to the nearby habitants and to avoid contamination of water courses from wastewater drainage. To prevent such contamination, wastewater generated at the campsites shall be discharged into soak pits. Human excreta shall be treated though septic tanks prior to discharge and shall conform to directives and guidelines of the State. Water accumulated in tires, empty vessels and containers of all nature will be regularly cleaned to avoid the related health hazards.

111.13 Control and Disposal of Wastes

The Contractor shall control the disposal of all forms of waste generated by the construction operations and in all associated activities. No uncontrolled deposition or dumping shall be permitted. Wastes to be so controlled shall include, but shall not be limited to, all forms of fuels and engine oils, all types of bitumen, cement, surplus aggregates, gravels, bituminous mixtures etc. The Contractor shall make specific provision for the proper disposal of these and any other waste products, conforming to local regulations and acceptable to the Engineer.

Spilling of oil and bituminous products during construction and transport shall be avoided to reduce the chances of contamination of surface as well as ground water.

111.14 Transport of Hazardous Materials

Transport of al hazardous materials, in bulk or in sealed containers, shall meet the requirements of the State regulations. Prior to ordering transport of hazardous material in

bulk, the Contractor must obtain the approval of the relevant authority as well as of the Engineer. Precautionary measures and conformity with regulations shall be stated in a Method Statement for the approval of the Engineer. Sealed containers of hazardous materials shall be stored in a well-ventilated room, well guarded and secured.

111.15 Emergency Response

The Contractor shall plan and provide remedial measures to be implemented in the event of occurrence of emergencies such as spillages of oil or bitumen or chemicals. The Contactor shall provide the Engineer with a statement of the measures he intends to implement in the event of such an emergency, which shall include a statement of how he intends to provide personnel adequately trained to implement such measures.

111.16 Measurement for payment

The compliance of all provisions made in this Clause 111 shall be deemed to be incidental to the work and no separate measurement shall be made. The Contractor shall be deemed to have made allowance for such compliance with these provisions in the preparation of his prices for items of work included in the Bill of Quantities and full compensation for such compliance shall be deemed to be covered by those prices."

112 ARRANGEMENT FOR TRAFFIC DURING CONSTRUCTION

112.1 General

The Contractor shall at all times, carry out work on the highway in a manner creating least interference to the flow of traffic while consistent with the satisfactory execution of the same. For all works involving improvements to the existing highway, the Contractor shall, in accordance with the directives of the Engineer, provide and maintain, during execution of the work, a passage for traffic either along a part of the existing carriageway under improvement or along a temporary diversion constructed close to the highway. Before taking up any construction or maintenance operation, the Contractor shall prepare a Traffic Management Plan for each work zone and submit it to the Engineer for prior approval. This plan should include inter alia :

i) A qualified safety officer with support staff to serve as a site safety team

ii) Provision of traffic safety devises as per IRC:SP 55 with the following specifications

  a) Signages of retro-reflective sheet of high intensity grade

b) Delineators in the form of cones/drums made of plastic/rubber having retro-reflective red and white bands, at a spacing of 5 m along with a reflective tape to be tied in between the gaps of cones/drums. A bulb using solar energy is to be placed on the top of the cone/drum for delineation in the dark hours and night.

c) Barricades using iron sheet with adequate iron railing/frame painted with retro-reflective paint in the alternate yellow and black & white stripes. Warning lights at 5 m spacing shall be mounted on the barricades and kept lit in dark hours and night.

d) Road markings with hot applied thermoplastic paint with glass beads.

iii) Safety measures for the workers engaged including personal protection equipment

iv) First aid and emergency response arrangements

v) Details and drawings of arrangements in compliance with other sub Sections of this Section.

112.2. Passage of Traffic along a Part of the Existing Carriageway under improvement

For widening/strengthening existing carriageway where part width of the existing carriageway is proposed to be used for passage of traffic, treated shoulders shall be provided on the side on which work is not in progress. The treatment to the shoulder shall consist of providing atleast 150 mm thick granular (WMM/WBM) base course covered with bituminous surface dressing in a width of atleast 1.5 m and the surface shall be maintained throughout the period during which traffic uses the same to the satisfaction of the Engineer. The continuous length in which such work shall be carried out, would be limited normally to 500 m at a place. However, where work is allowed by the Engineer in longer stretches passing places atleast 20 m long with additional paved width of 2.5 m shall be provided at every 0.5 km interval.

In case of widening existing two-lane to four-lane, the additional two-lanes would be constructed first and the traffic diverted to it and only thereafter the required treatment to the existing carriageway would be carried out. However, in case where on the request of the Contractor, work on existing two-lane carriageway is allowed by the Engineer with traffic using part of the existing carriageway, stipulations as in para above shall apply.

After obtaining permission of the Engineer, the treated shoulder shall be dismantled, the debris disposed of and the area cleared as per the direction of the Engineer.

112.3 Passage of Traffic along a Temporary Diversion

In stretches where it is not possible to pass the traffic on part width of the carriageway, a temporary diversion shall be constructed with 7 m carriageway and 2.5 m earthen shoulders on each side (total width of roadway 12 m) with the following provision for road crust in the 7 m width:

i) 200 mm (compacted) granular sub-base;

ii) 225 mm (compacted) granular base course; and

iii) Premix carpet with Seal Coat/Mix Seal Surfacing

The location of such stretch, alignment and longitudinal section of diversion including junctions and temporary cross drainage provision shall be as approved by the Engineer.

112.4 Traffic Safety and Control

The Contractor shall take all necessary measures for the safety of traffic during construction and provide, erect and maintain such barricades, including signs, marking, flags, lights and flagmen as per the traffic management plan submitted by the Contractor and approved by the Engineer, referred to in Sub-Section 112.1. Before taking up any construction, an agreed phased programme for the diversion of traffic on the highway shall be drawn up in consultation with the Engineer.

The barricades erected on either side of the carriageway/portion of the carriageway closed to traffic, shall be of strong design to resist violation, and painted with alternate black and white stripes. Red lanterns or warning lights of similar type shall be mounted on the barricades at night and kept lit throughout from sunset to sunrise.

At the points where traffic is to deviate from its normal path (whether on temporary diversion or part width of the carriageway) the channel for traffic shall be clearly marked with the aid of pavement markings, painted drums or a similar device to the directions of the Engineer. At night, the passage shall be delineated with lanterns or other suitable light source.

One-way traffic operation shall be established whenever the traffic is to be passed over part of the carriageway inadequate for two-lane traffic. This shall be done with the help of temporary traffic signals or flagmen kept positioned on opposite sides during all hours. For regulation of traffic, the flagmen shall be equipped with red and green flags and lanterns/ lights.

On both sides, suitable regulatory/warning signs as approved by the Engineer shall be installed for the guidance of road users. On each approach, at least two signs shall be put up, one close to the point where transition of carriageway begins and the other 120 m

away. The signs shall be of approved design and of reflective type, as directed by the Engineer.

112.5 Maintenance of Diversions and Traffic Control Devices

Signs, lights, barriers and other traffic control devices, as well as the riding surface of diversions shall be maintained in a satisfactory condition till such time they are required and as directed by the Engineer. The temporary traveled way shall be kept free of dust by frequent applications of water, if necessary.

112.6 Measurements for Payment and Rate

All arrangements for traffic during construction including provision of temporary cross drainage structures, if required and treated shoulder as described in Section 112.2 shall be measured and paid as per Contract rates for the corresponding items. However their maintenance, dismantling and clearing debris, where necessary, shall be considered as incidental to the works and shall be the Contractor's responsibility.

The construction of temporary diversion including temporary cross drainage structures as described in Section 112.3, shall be measured in linear metre and the unit contract rate shall be inclusive of full compensation for construction (including supply of material, labour, tools, etc.), maintenance, final dismantling, and disposal.

Traffic safety and control described in Section 112.1, 112.4 and 112.5 shall not be paid separately and shall be incidental to the work unless otherwise stipulated in the Contract.

113 GENERAL RULES FOR THE MEASUREMENT OF WORKS FOR PAYMENT

113.1 General

All measurements shall be made in the metric system. Different items of work shall be measured in accordance with the procedures set forth in the relevant Sections read in conjunction with the General Conditions of Contract. The same shall not, however, apply in the case of lumpsum contracts.

All measurements and computations, unless otherwise indicated, shall be carried nearest to the following limits:

i)	length and width	10 mm
ii)	height, depth or thickness of	
	a) earthwork, subgrade,	5 mm
	b) sub-bases, bases, surfacing and structural members	2.5 mm

iii)	area	0.01 sq.m
iv)	volume	0.01 cu.m

In recording dimensions of work, the sequence of length, width and height or depth or thickness shall be followed.

113.2 Measurement of Lead for Materials

Where lead is specified in the Contract for construction materials, the same shall be measured as described hereunder:

Lead shall be measured over the shortest practicable route and not the one actually taken and the decision of the Engineer in this regard shall be taken as final. Distances upto and including 100 m shall be measured in units of 50 m, exceeding 100 m but not exceeding 1 km in units of 100 m and exceeding 1 km in units of 500 m, the half and greater than half of the unit shall be reckoned as one and less than half of the unit ignored. In this regard, the source of the material shall be divided into suitable blocks and for each block, the distance from the centre of placing pertaining to that block shall be taken as the lead distance.

113.3 Measurement of Pavement Thickness for Payment on Volume Basis

The finished thickness of sub-base, base and bituminous courses to be paid on volume basis shall be computed in the following manner:

Levels shall be taken before and after construction, at the grid of points 10 m centre-to-centre longitudinally in straight reaches but 5 m at curves. Normally, on two-lane roads, the levels shall be taken at four positions transversely, at 0.75 and 2.75 m from either edge of the carriageway and on single-lane roads, these shall be taken at two positions transversely, being at 1.25 m from either edge of the carriageway. For multi-lane roads, levels shall be taken at two positions transversely for each lane at 0.75 m from either edge and remaining levels at equi-distance in the balance portion of carriageway. Road with paved shoulder on both sides for this purpose shall be treated as three-lane road.

Suitable references for the transverse grid lines should be left in the form of embedded bricks on either ends or by other means so that it is possible to locate the grid points for level measurements after each successive course is laid.

For pavement courses laid only over widening portions, atleast one line of levels shall be taken on each strip of widening, or more depending on the width of widening as decided by the Engineer.

Notwithstanding the above, the measurements may be taken at closer intervals also, if so desired by the Engineer, the need for which may arise particularly in the case of estimation of the volume of the material for profile corrective course (leveling course). The average thickness of the pavement course in any area shall be the arithmetic mean of the difference of levels before and after construction at all the grid points falling in that area, provided that the thickness of finished work shall be limited to those shown on the drawings or approved by the Engineer in writing.

As supplement to level measurements, the Engineer shall have the option to take cores/ make holes to check the depth of construction. The holes made and the portions cut for taking cores shall be made good by the Contractor by laying fresh mix/material including compacting as required at his own cost immediately after the measurements are recorded.

113.4 Checking of Pavement Thickness for Payment on Area Basis

Where payment for any bituminous course in Section 500 is allowed to be made on the area basis, the Engineer may have its thickness checked with the help of a suitable penetration gauge at regular intervals or other means as he may decide. In case thickness of the pavement is less, the same shall be regulated as per the provisions of Section 900.

113.5 Measurement of Bituminous Courses for Payment on Weight Basis

Plant-mixed bituminous materials for pavement courses where designated to be paid on weight basis shall be weighed on accurate scales approved by the Engineer. Approved scales shall mean scales that are of size, capacity, kind and type suitable for the weighing to be done, and these shall be properly installed and maintained. Prior to the use of the scales and as frequently thereafter as the Engineer may deem necessary to ensure accuracy, the scales shall be checked and approved by the Engineer, or the Engineer may direct the Contractor to have the scales checked by other competent agency at the cost of the Contractor.

Location of the scales shall be as designated by the Engineer. Trucks used for hauling the material to be weighed shall be weighed empty daily at such times as the Engineer directs, and each truck shall bear a plainly legible identification mark.

For materials specified to be measured by weight, the Engineer will have the option to make measurements of the finished work by volume in accordance with Section 113.3 and such volumes shall be converted into weight for payment purposes. The factor for conversion from volume measurement to weight measurement shall be computed from

the representative density of the compacted material at site determined at locations approved by the Engineer.

114 SCOPE OF RATES FOR DIFFERENT ITEMS OF WORK

114.1 For item rate contracts, the contract unit rates for different items of work shall be payment in full for completing the work to the requirements of the Specifications including full compensation for all the operations detailed in the relevant Sections of these Specifications under "Rates". In the absence of any directions to the contrary, the rates are to be considered as the full inclusive rate for finished work covering all labour, materials, wastage, temporary work, plant, equipment, over-head charges and profit as well as the general liabilities, performance of other obligations, insurance and risks arising out of the Conditions of Contract.

114.2 The item rates quoted by the Contractor shall, unless otherwise specified, also include compliance with/supply of the following:

i) General works such as setting out, clearance of site before setting out and clearance of works after completion;

ii) A detailed programme for the construction and completion of the work (using CPM/PERT techniques) giving, in addition to construction activities, detailed network activities for the submission and approval of materials, procurement of critical materials and equipment, fabrication of special products/equipment and their installation and testing, for all activities of the Engineer/Employer that are likely to affect the progress of work, etc., including updating of all such activities on the basis of the decisions taken at the periodic site review meetings or as directed by the Engineer;

iii) Samples of various materials proposed to be used on the Works for conducting tests thereon as required as per the provisions of the Contract;

iv) Cost of laying trial stretches;

v) Design of mixes as per the relevant Sections of the Specifications giving proportions of ingredients, sources of aggregates and binder along with accompanying trial mixes as per the relevant Sections of these Specifications to the submitted to the Engineer for his approval before use on the Works;

vi) Detailed design calculations and drawings for all Temporary Works (such as form-work, staging, centering, specialized constructional handling and launching equipment and the like);

vii) Detailed drawings for templates, support and end anchorage, details for pre-stressing cable profiles, bar bending and cutting schedules for reinforcement, material lists for fabrication of structural steel, etc;

viii) Mill test reports for all mild and high tensile steel and cast steel as per the relevant provisions of the Specifications;

ix) Testing of various finished items and materials including bitumen, cement, concrete, bearings as required under these Specifications and furnishing test reports/certificates;

x) Inspection Reports in respect of formwork, staging, reinforcement and other items of work as per the relevant Specifications;

xi) Any other data which may be required as per these Specifications or the Conditions of Contract or any other annexures/schedules forming part of the Contract;

xii) Any other item of work which is not specifically provided in the Bill of Quantities but which is necessary for complying with the provisions of the Contract;

xiii) All temporary works, formwork and false work not included as separate item in the BOQ;

xiv) Establishing and running a laboratory with facilities for testing for various items or works as specified in Section 900 and other relevant Sections;

xv) Cost of in-built provisions for Quality Assurance;

xvi) Cost of safeguarding the environment; and

xvii) Cost of providing “as-built drawings” in original and two sets of prints.

114.3 Portions of road works beyond the limits and/or any other work may be got constructed by the Employer directly through other agencies. Accordingly, other agencies employed by the Employer may be working in the vicinity of the Works being executed by the Contractor. The Contractor shall liaise with such agencies and adjust his construction programme for the completion of work accordingly and no claim or compensation due to any reason whatsoever will be entertained on this account. The Employer will be indemnified by the Contractor for any claims from other agencies on this account.

115 METHODOLOGY AND SEQUENCE OF WORK

115.1 Prior to start of the construction activities at site, the Contractor shall, within 28 days after the date of the agreement unless otherwise stipulated in the Contract, submit to the Engineer for approval, the detailed method statement. The method statement shall be submitted in two parts.

115.2 The general part of the method statement shall describe the Contractor's proposals regarding preliminary works, common facilities and other items that require consideration at the early stage of the contract. The general part shall include information on:

a) Sources of materials like coarse aggregates and fine aggregates, quantity and quality of materials available in different sources;

b) Sources of manufactured materials like bitumen, cement, steel reinforcement, pre-stressing strands and bearings etc. He shall also submit samples/test certificates of materials for consideration of the Engineer;

c) Locations of the site facilities such as batching plant, hot mix plant, crushing plant, aggregate processing unit etc;

d) Details of facilities available for transportation of men/material and equipments;

e) Information on procedure to be adopted by the Contractor for prevention and mitigation of negative environmental impact due to construction activities;

f) Safety and traffic arrangement during construction:

g) Any other information required by the Engineer.

The general part of the QA programme under sub-Section 105.3 shall accompany the method statement.

115.3 Special part of the method statement shall be submitted to the Engineer by the Contractor for each important item of work as directed by the Engineer. The statement shall be submitted at least 4 weeks in advance of the commencement of the activity of item of work unless otherwise stipulated in the contract. The statement shall give information on:

a) Details of the personnel both for execution and quality control of the work;

b) Equipment deployment with details of the number of units, capacity, standby arrangement;

c) Sequence of construction and details of temporary or enabling works like diversion, cofferdam, formwork including specialized formwork for superstructure, details of borrow areas, method of construction of

embankment, sub-grade and pavement, pile concreting, proprietary processes and products and equipments to be deployed. Wherever required technical literature, design calculations and drawings shall be included in the method statement;

d) Testing and acceptance procedure including documentation;

e) The special part of the QA programme under sub-Section 105.3 for the particular item of work shall accompany the method statement for the concerned activity.

The Engineer shall examine and approve the method statement with the required modifications. The modified method statement if required shall be submitted within 14 days of the receipt of the Engineer's approval. The sole responsibility for adequacy and safety of the method adopted by the Contractor shall rest on the Contractor irrespective of any approval given by the Engineer.

115.4 Approval of proprietary products/processes/systems.

Within 90 days of the signing of agreement, the Contractor shall submit the following information for all proprietary products, process or any other item proposed to be used in the work, for approval of the Engineer.

a) Name of the manufacturer and name of the product/ process/system along with authenticated copies of the license/collaboration agreement;

b) General features of the product/process/system;

c) Details of the product development and development testing;

d) Acceptance test and criteria;

e) Installation procedure;

f) Maintenance procedure and schedule;

g) Warranty proposal.

The Engineer may order additional test for the purpose of acceptance. Additional charges for test, if any, for the product/process/system shall be borne by the Contractor.

116 CRUSHED STONE AGGREGATES

Where the terms crushed gravel/shingle, crushed stone, broken stone or stone aggregate appear in any part of the Tender Documents or Drawings issued for work, they refer to crushed gravel/crushed shingle/crushed stone aggregate obtained from integrated crushing

plant having appropriate primary crusher, secondary cone crusher, vertical shaft impactor and vibratory screen unless specified otherwise.

117 APPROVAL OF MATERIALS

Approval of all sources of material for work shall be obtained in writing from the Engineer before their use on the works.

118 SUPPLY OF QUARRY SAMPLES

Raw and processed samples of the mineral aggregates from the approved quarry shall be submitted by the Contractor at his cost.

119 USE OF SURFACES BY CONSTRUCTION TRAFFIC

119.1 Ordinarily, no construction traffic shall be allowed on pavement under construction unless authorized by the Engineer. Even in that case, the load and intensity of construction traffic should be so regulated that no damage is caused to the sub-grade or pavement layers already constructed. Where necessary, service roads shall be constructed for this purpose and the same shall be considered as incidental to the work.

119.2 The wheels or the tracks of plant moving over the various pavement courses shall be kept free of deleterious materials.

119.3 Bituminous base course shall be kept clean and uncontaminated as long as the same remains uncovered by a wearing course or surface treatment. The only traffic permitted access to the base course shall be that engaged in laying and compacting the wearing course or that engaged on such surface treatment where the base course is to be blinded and/or surface dressed. Should the base course or tack coat on the base course become contaminated, the Contractor shall make good by clearing it to the satisfaction of the Engineer, and if this is impracticable, by removing the layer and replacing it to Specifications without any extra cost to the Employer.

120 FIELD LABORATORY

120.1 Scope

The work covers the provision and maintenance of an adequately equipped field laboratory as required for site control on the quality of materials and the works.

120.2 Description

The Contractor shall arrange to provide fully furnished and adequately equipped field laboratory. The field laboratory shall preferably be located adjacent to the site office of the Engineer and provided with amenities like water supply, electric supply etc. as for the site office of the Engineer in Section 120.2.

The floor space for the field laboratory shall include space for the storage of samples. The remaining space shall be provided for the installation of equipment, laboratory tables and cup boards, working space for carrying out various laboratory tests, besides a wash basin, toilet facility and a curing tank for the curing of samples, around 4 m x 2 m x 1 m in size and a fume chamber. Wooden/concrete working table with a working platform area of about1 m x 10 m shall be provided against the walls, also providing wooden cupboards above and below the working tables to store accessories such as, sample moulds etc. Atleast 4 racks of slotted angles and M.S. sheets the size 1800 mm x 900 mm x 375 mm and atleast 6 stools for laboratory test operators of Godrej or equivalent make shall also be provided.

120.3 Laboratory Equipment

For the purpose of establishing laboratory, projects are categorized under following categories:

a) Projects costing Rs 100 crore and above: and

b) Projects costing less than Rs 100 crore.

The items of laboratory equipment shall be provided in the field laboratory depending upon the items to be executed as per Table 100-2:

Table 100-2 List of Laboratory Equipments

Sl. No	Name	Project costing less than Rs 100 Cr	Project costing Rs 100 Cr or more
A	**GENERAL**		
1	Weigh Balances		
	a) 7 kg to 10 kg capacity semi-self indicating type – Accuracy 1 gm	1 No	2 Nos
	b) 500 gm capacity–semi–self indicating Electronic Type Accuracy 0.01 gm	1 No	2 Nos

Sl. No	Name	Project costing less than Rs 100 Cr	Project costing Rs 100 Cr or more
	c) Pan balance 5 kg capacity Accuracy 0.5 gm	1 No	3 Nos
	d) Platform scale–300 kg capacity	1 No	1 No
	e) Chemical Balance 100 gm Capacity-accuracy 0.001	–	1 No
2	Oven-electrically operated, thermostatically controlled (including thermometer), stainless steel interio a) From 100°C to 220°C Sensitivity 1°C	1 No	1 No
3	Sieves : as per IS:460-1962 a) I.S. sieves 450 mm internal dia of sieve sets as per BIS of required sieve sizes complete with lid and pan	1 set	2 sets
	b) IS sieve 200 mm internal dia (brass frame and steel/or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid and pan	2 sets	2 sets
4	Sieve shaker capable of taking 200 mm and 450 mm dia sieves-electrically operated with time switch assembly (As per IS)	1 No	1 No
5	200 tonnes compression testing machine	1 No	1 No
6	Stop watches 1/5 sec. accuracy	1 No	2 Nos
7	Glassware comprising beakers, pipettes, dishes, measuring cylinders (100 to 1000 cc capacity) glass rods and funnels, glass thermometers range 0°C to 100°C and metallic thermometers range up to 300°C.	As req	1 Doz
8	Hot plates 200 mm dia (1500 watt.)	1 No	2 Nos
9	Enamel trays a) 600 mm x 450 mm x 50 mm	2 Nos	6 Nos
	b) 450 mm x 300 mm x 40 mm	2 Nos	6 Nos
	c) 300 mm x 250 mm x 40 mm	2 Nos	6 Nos

Sl. No	Name	Project costing less than Rs 100 Cr	Project costing Rs 100 Cr or more
	d) Circular plates of 250 mm dia	2 Nos	6 Nos
10	Water Testing Kit	1 No	1 No
B	**FOR SOILS**		
1	Water still	–	1 No
2	Liquid limit device with ASTM grooving tools as per IS:2720	1 No	2 Nos
3	Sampling pipettes fitted with pressure and suction inlets, 10 ml. Capacity	1 set	1 set
4	Compaction apparatus (proctor) as per IS:2720 (Part 7) complete with collar, base plate and hammer and all other accessories	1 No	2 Nos
5	Modified AASHTO Compaction apparatus as per IS:2720 (Part 8) 1974 or Heavy Compaction Apparatus as per IS complete with collar, base plate hammer and all other accessories.	1 No	2 Nos
6	Sand pouring cylinder with conical funnel and tap and complete as per IS:2720 (Part 28) 1974 including modern equipment.	2 Nos	6 Nos
7	Sampling tins with lids 100 mm dia x 75 mm ht. ½ kg capacity and miscellaneous items like moisture tins with lid 50 grams etc.	4 Nos	24 Nos
8	Lab CBR testing equipment for conducting CBR testing, load frame with 5 Tonne capacity, electrically operated with speed control as per IS 2720 (Part 16) and consisting of following: a) CBR moulds 150 mm dia – 175 mm ht. Complete with collar, base plate etc. b) Tripod stands for holding dial gauge holder c) CBR plunger with settlement dial gauge holder d) Surcharge weight 147 mm dia 2.5 kg wt. With central hole	1 Set	1 Set

Sl. No	Name	Project costing less than Rs 100 Cr	Project costing Rs 100 Cr or more
	e) Spacers disc 148 mm dia 47.7 mm ht. With handle f) Perforated plate (Brass) g) Soaking tank for accommodating 6 CBR mouldsh) Proving rings of 1000kg, 2500kg capacity i) Dial gauges 25 mm travel – 0.01 mm/division		
9	Standard penetration test equipment	1 No	2 Nos
10	Nuclear moisture Density meter or equivalent	–	1 No
11	Speedy moisture meter complete with chemicals	1 No	2 Nos
12	Unconfined Compression Test Apparatus	1 No	1 No
C	**FOR BITUMEN AND BITUMINOUS MIXES**		
1	Constant temperature bath for accommodating bitumen test specimen, electrically operated, and thermostatically controlled	1 No	1 No
2	Penetrometer automatic type, including adjustable weight arrangement and needles as per IS:1203-1958	1 No	1 No
3	Soxhlet extraction or centrifuge type apparatus complete with extraction thimbles with solvent and filter paper	1 No	1 No
4	Bitumen laboratory mixer including required accessories	1 No	1 No
5	Marshall compaction apparatus automatically operated as per ASTM 1559-62 T complete with accessories	1 set	1 set
6	Distant reading thermometer	–	1 No

Sl. No	Name	Project costing less than Rs 100 Cr	Project costing Rs 100 Cr or more
7	Rifle box	–	1 No
8	Automatic Asphlat content Meter	–	1 No
9	Thin film over test apparatus for modified binder either with PMB or CRMB	–	1 set
10	Mastic Asphalt Hardness testing equipment	–	1 set
11	Sand Equivalent test apparatus	1 set	1 set
12	Core cutting machine suitable for upto 150 mm dia core	1 set	1 set
13	Thermometers	4 sets	4 sets
D	**FOR CEMENT, CEMENT CONCRETE AND MATERIALS**		
1	Water still	1 No	1 No
2	Vicat needle apparatus for setting time with plungers as per IS:269-1967	1 No	1 No
3	Moulds a) 150 mm x 300 mm ht. Cylinder with capping component along with the capping set and compound as per IS	As req	As req
	b) Cube 150 mm, and 100 mm (each size)	As req	As req
4	Concrete permeability apparatus	–	1 No
5	High frequency mortar cube vibrator for cement testing	–	1 No
6	Concrete mixer power driven, 1 cu.ft. capacity	–	1 No
7	Variable frequency and amplitude vibrating table size 1 m x 1 m as per the relevant British Standard	–	1 No

Sl. No	Name	Project costing less than Rs 100 Cr	Project costing Rs 100 Cr or more
8	Flakiness index test apparatus	1 No	1 No
9	Aggregate impact test apparatus as per IS:2386 (Part 4) 1963	1 No	1 No
10	Los-Angeles abrasion test apparatus as per IS:2386 (Part 4) 1963	1 No	1 No
11	Flow table as per IS:712-1973	–	1 No
12	Equipment for slump test	1 No	4 Nos
13	Equipment for determination of specific gravity for fine and coarse aggregate as per IS:2386 (Part 3) 1963	1 No	4 Nos
14	Compression and Flexural strength testing machine of 200 T capacity with additional dial for flexural testing	1 No	1 No
15	Core cutting machine with 10 cm dia diamond cutting edge	1 No	2 Nos
16	Needle vibrator	2 Nos	4 Nos
17	Air entrainment meter	–	1 No
18	0.5 Cft, 1 Cft cylinder for checking bulk density of aggregate with tamping rod	As req	As req
19	Soundness testing apparatus for cement (Lee chattier)	1 set	1 set
E	**FOR CONTROL OF PROFILE AND SURFACE EVENNESS**		
1	Total Station	1 No	1 No

Sl. No	Name	Project costing less than Rs 100 Cr	Project costing Rs 100 Cr or more
2	Precision automatic level with micrometer attachment	1 set	2 sets
3	Distomat or equivalent	1 set	1 set
4	Theodolite – Electronically operated with computerised output attachment	1 set	1 set
5	Precision staff	2 sets	3 sets
6	3 meter straight edge and measuring wedge	1 set	1 set
7	Camber template 2 Lane		
	a) Crown type cross-section	1 set	1 set
	b) Straight run cross-section	2 sets	2 sets
8	Steel tape		
	a) 5 m long	2 sets	2 sets
	b) 10 m long	2 sets	2 sets
	c) 20 m long	2 sets	2 sets
	d) 30 m long	2 sets	2 sets
	e) 50 m long	1 set	2 sets

Note : The items and their numbers listed above in this Section shall be decided by the Engineer as per requirements of the Project and modified accordingly.

120.4 Ownership

The field laboratory building and equipment shall be the property of the Contractor. The Employer and the Engineer shall have free access to the laboratory during construction and defects liability period of the Contract.

120.5 Maintenance

The Contractor shall arrange to maintain the field laboratory in a satisfactory manner until the issue of Taking Over Certificate for the complete work. Maintenance includes all activities described in Section 120.4.

120.6 Rate

Provision and maintenance of the field laboratory is not a payable item as it is incidental to the work.

121 SUPPLY OF PROJECT RECORD

121.1 Scope

The work covers the supply digital record of project events in digital format (DVD/Flash Drive) including coloured photographs mounted on albums to serve as a permanent record of the work needed for an authentic documentation, as approved by the Engineer.

121.2 Description

The Contractor shall provide the following project records in digital format (DVD/Flash Drive) as directed by the Engineer :

i) Record of work in each workfront : It shall cover the status of each workfront before start of work, during various stages of construction and after completion duly including the arrangements made (day & night) for traffic during construction (This shall be need based or as directed by the Engineer);

ii) Record of quarry sites, plant sites, camp sites including labour camps, haul roads, access roads, etc. on quarterly basis;

iii) Record of all accidents on project road/ various sites (quarry, plant, camp, etc.)

The record shall be taken by a professional with a digital camera capable of taking still as well as video images having the facility to record the date and the background commentary. The Contractor shall keep separate discs/drives, one with the Engineer and the other with the Employer and update the data in these discs/drives on monthly basis. Separately, a video (in digital format) of maximum one hour duration covering interesting and novel features of the work duly editing the above master disc/drive shall also be maintained, one copy each kept with the Engineer and the Employer and updated on monthly basis. All recording shall be done in the presence of the Engineer’s Representative who will certify in writing the recording.

121.3 Measurements for Payment

Supply of two copies of all digital records as above and colour record photographs mounted

in the albums project shall be measured as one item for the project.

Supply of additional prints of colour record photograph if requested shall be measured in number of additional prints supplied.

121.4 Rate

Supply of project record in digital format in two copies (one for the Engineer and the other for the Employeer) including video recordings updated on monthly basis throughout the construction period shall be measured as one single item.

200

Site Clearance

201 CLEARING AND GRUBBING

201.1 Scope

This work shall consist of cutting, removing and disposing of all materials such as trees, bushes, shrubs, stumps, roots, grass, weeds, top organic soil not exceeding 150 mm in thickness, rubbish etc., which in the opinion of the Engineer are unsuitable for incorporation in the works, from the area of road land containing road embankment, drains, cross-drainage structures and such other areas as may be specified on the drawings or by the Engineer. It shall include necessary excavation, backfilling of pits resulting from uprooting of trees and stumps to required compaction, handling, salvaging, and disposal of cleared materials with all leads and lights. Clearing and grubbing shall be performed in advance of earthwork operations and in accordance with the requirements of these Specifications.

201.2 Preservation of Property/Amenities

Roadside trees, shrubs, any other plants, pole lines, fences, signs, monuments, buildings, pipelines, sewers and all highway facilities within or adjacent to the highway which are not to be disturbed shall be protected from injury or damage. The Contractor shall provide and install at his own cost, suitable safeguards approved by the Engineer for this purpose.

During clearing and grubbing, the Contractor shall take all adequate precautions against soil erosion, water pollution, etc., and where required, undertake additional works to that effect vide Clause 306. Before start of operations, the Contractor shall submit to the Engineer for approval, his work plan including the procedure to be followed for disposal of waste materials, etc., and the schedules for carrying out temporary and permanent erosion control works as stipulated in Clause 306.3.

201.3 Methods, Tools and Equipment

Only such methods, tools and equipment as are approved by the Engineer and which will not affect the property to be preserved shall be adopted for the Work. If the area has thick vegetation/roots/trees, a crawler or pneumatic tyred dozer of adequate capacity may be used for clearance purposes. The dozer shall have ripper attachments for removal of tree stumps. All trees, stumps, etc., falling within excavation and fill lines shall be cut to such depth below ground level that in no case these fall within 500 mm of the subgrade. Also, all vegetation such as roots, under-growth, grass and other deleterious matter unsuitable for incorporation in the embankment/subgrade shall be removed between fill lines to the satisfaction of the Engineer. All branches of trees extending above the roadway shall be trimmed as directed by the Engineer.

All excavations below the general ground level arising out of the removal of trees, stumps, etc., shall be filled with suitable material and compacted thoroughly so as to make the surface at these points conform to the surrounding area.

Ant-hills both above and below the ground, as are liable to collapse and obstruct free subsoil water flow shall be removed and their workings, which may extend to several metres, shall be suitably treated.

201.4 Disposal of Materials

All materials arising from clearing and grubbing operations shall be taken over and shall be disposed of by the Contractor with all leads and lifts. The rates deemed to include credit towards value of usable materials and salvage value of unusable materials. The off-set price of cut trees and stumps as per guidelines/ estimates of State Forest Department shall be deducted from the amount due to the Contractor and deposited with the State Forest Department. The rate is deemed to account for this off-set price also.

201.5 Measurements for Payment

Clearing and grubbing for road embankment, drains and cross-drainage structures shall be measured on area basis in terms of hectares. Clearing and grubbing of borrow areas shall be deemed to be a part of works preparatory to embankment construction and shall be deemed to have been included in the rates quoted for the embankment construction item and no separate payment shall be made for the same. Cutting of trees upto 300 mm in girth including removal of stumps and roots, and trimming of branches of trees extending above the roadway shall be considered incidental to the clearing and grubbing operations.

Cutting of trees, excluding removal of stumps and roots of trees of girth above 300 mm shall be measured in terms of number according to the sizes given below :-

i)	Above	300 mm	to	600 mm
ii)	Above	600 mm	to	900 mm
iii)	Above	900 mm	to	1800 mm
iv)	Above	1800 mm		

Removal of stumps and roots including backfilling with suitable material to required compaction shall be a separate item and shall be measured in terms of number according to the sizes given below:-

i)	Above	300 mm	to	600 mm
ii)	Above	600 mm	to	900 mm
iii)	Above	900 mm	to	1800 mm
iv)	Above	1800 mm		

For the purpose of cutting of trees and removal of roots and stumps, the girth shall be measured at a height of 1 metre above ground or at the top of the stump if the height of the stump is less than one metre from the ground.

201.6 Rates

201.6.1 The Contract unit rates for the various items of clearing and grubbing shall be payment in full for carrying out the required operations including full compensation for all labour, materials, tools, equipment and incidentals necessary to complete the work. These will also include removal of stumps of trees less than 300 mm girth excavation and back-filling to required density, where necessary, and handling, giving credit towards salvage value disposing of the cleared materials with all lifts and leads. Ground levels shall be taken prior to and after clearing and grubbing. Levels taken prior to clearing and grubbing shall be the base level and will be accordingly used for computation of quantity of material arising due to clearing and grubbing, including the computation of unsuitable material, if any, which may be required to be removed as per the approval of the Engineer. The levels taken subsequent to clearing and grubbing shall be the base level for computation of earthwork for embankment. Clearing and grubbing shall be restricted to 150 mm only for payment purpose.Where clearing and grubbing is done a level beyond 150 mm, the excess excavation shall be made good as per Clause 301.3.3 and 301.6 to the satisfaction of the Engineer prior to taking up earthwork. This shall not be paid and shall be treated as part of clearing and grubbing.

201.6.2 The Contract unit rate for cutting trees of girth above 300 mm shall include handling, giving credit towards salvage value disposing of the cleared materials with all lifts and leads.

201.6.3 The Contract unit rate for removal of stumps and roots of trees girth above 300 mm shall include excavation and backfilling with suitable material to required compaction, handling, giving credit towards salvage value disposing of the cleared materials with all lifts and leads.

201.6.4 The Contract unit rate is deemed to include credit towards value of usable materials and salvage value of unusable materials. The off-set price of cut trees and stumps as per guidelines/ estimates of State Forest Department shall be deducted from the amount due to the Contractor and deposited with the State Forest Department. The rate is deemed to account for this off-set price also.

201.6.5 Where a Contract does not include separate items of clearing and grubbing, the same shall be considered incidental to the earthwork items and the Contract unit prices for the same shall be considered as including clearing and grubbing operations.

202 DISMANTLING CULVERTS, BRIDGES AND OTHER STRUCTURES/ PAVEMENTS

202.1 Scope

This work shall consist of dismantling and removing existing culverts, bridges, pavements, kerbs and other structures like guard-rails, fences, utility services, manholes, catch basins, inlets, etc., from the right of way which in the opinion of the Engineer interfere with the construction of road or are not suitable to remain in place, and of giving credit towards salvage value disposing of the surplus/unsuitable materials including those remaining after back filling the resulting trenches and pits.

Existing culverts, bridges, pavements and other structures which are within the highway and which are designated for removal, shall be removed upto the limits and extent specified in the drawings or as indicated by the Engineer.

Dismantling and removal operations shall be carried out with such equipment and in such a manner as to leave undisturbed, adjacent pavement, structures and any other work to be left in place.

All operations necessary for the removal of any existing structure which might endanger new construction shall be completed prior to the start of new work.

202.2 Dismantling Culverts and Bridges

The structures shall be dismantled carefully and the resulting materials so removed as not to cause any damage to the part of the structure to be retained and any other properties or structures nearby.

Unless otherwise specified, the superstructure portion of culverts/bridges shall be entirely removed and other parts removed below the ground level or as necessary depending upon the interference they cause to the new construction. Removal of overlying or adjacent material, if required in connection with the dismantling of the structures, shall be incidental to this item.

Where existing culverts/bridges are to be extended or otherwise incorporated in the new work, only such part or parts of the existing structure shall be removed as are necessary and directed by the Engineer to provide a proper connection of the new work. The connecting edges shall be cut, chipped and trimmed to the required lines and grades without weakening or damaging any part of the structure to be retained. Due care should be taken to ensure that reinforcing bars which are to be left in place so as to project into the new work as dowels or ties are not injured during removal of concrete.

Pipe culverts shall be carefully removed in such a manner as to avoid damage to the pipes.

Steel structures shall, unless otherwise provided, be carefully dismantled in such a manner as to avoid damage to members thereof. If specified in the drawings or directed by the Engineer that the structure is to be removed in a condition suitable for re-erection, all members shall be match-marked by the Contractor with white lead print before dismantling; end pins, nuts, loose plates, etc. shall be similarly marked to indicate their proper location; all pins, pin holes and machined surfaces shall be painted with a mixture of white lead and tallow and all loose parts shall be securely wired to adjacent members or packed in boxes.

Timber structures shall be removed in such a manner as to avoid damage to such timber or lumber having salvage value as is designated by the Engineer.

202.3 Dismantling Pavements and Other Structures

In removing pavements, kerbs, gutters, and other structures like guard-rails, fences, manholes, catch basins, inlets, etc., where portions of the existing construction are to be left in the finished work, the same shall be removed to an existing joint or cut and chipped to a true line with a face perpendicular to the surface of the existing structure. Sufficient removal shall be made to provide for proper grades and connections with the new work as directed by the Engineer.

All concrete pavements, base courses in carriageway and shoulders etc., designated for removal shall be broken to pieces whose volume shall not exceed 0.02 cu.m. and used with the approval of the Engineer or disposed of.

202.4 Back-filling

Holes and depressions caused by dismantling operations shall be backfilled with excavated or other approved materials and compacted to required density as directed by the Engineer.

202.5 Disposal of Materials

All surplus materials shall be taken over by the Contractor which may either be re-used with the approval of the Engineer or disposed of with all leads and lifts.

202.6 Measurements for Payment

The work of dismantling shall be paid for in units indicated below by taking measurements before and after, as applicable:

i)	Dismantling brick/stone masonry/ concrete (plain and reinforced)	cu.m
ii)	Dismantling flexible and cement concrete pavement	cu.m

iii)	Dismantling steel structures	tonne
iv)	Dismantling timber structures	cu.m
v)	Dismantling pipes, guard rails, kerbs, gutters and fencing	inear m
vi)	Utility services	No.

202.7 Rates

The Contract unit rates for the various items of dismantling shall be paid in full for carrying out the required operations including full compensation for all labour, materials, tools, equipment, safeguards and incidentals necessary to complete the work. These will also include excavation and backfilling where necessary to the required compaction and for handling, giving credit towards salvage value disposing of dismantled materials with all lifts and leads.

The rates deemed to include crdit towards value of usable materials and salvage value of unusable materials.

300

Earthwork, Erosion Control and Drainage

301. EXCAVATION FOR ROADWAY AND DRAINS

301.1 Scope

This work shall consist of excavation, removal and disposal of materials necessary for the construction of roadway, side drains and waterways in accordance with requirements of these Specifications and the lines, grades and cross-sections shown in the drawings or as indicated by the Engineer. The cut material may be taken away by the Contractor for re-use or disposal. Hence, the scope shall include the a giving credit for suitable cut materials as also the salvage value and disposal of unsuitable cut materials in specified manner, trimming and finishing of the road to specified dimensions or as directed by the Engineer.

301.2 Classification of Excavated Material

301.2.1 Classification : All materials involved in excavation shall be classified by the Engineer in the following manner:

a) Soil :

This shall comprise topsoil, turf, sand, silt, loam, clay, mud, peat, black-cotton soil, soft shale or loose moorum, a mixture of these and similar material which yield to the ordinary application of pick, spade and/or shovel, rake or other ordinary digging equipment. Removal of gravel or any other modular material having dimension in any one direction not exceeding 75 mm shall be deemed to be covered under this category.

b) Ordinary Rock (not requiring blasting) This shall include :

i) rock types such as laterites, shales and conglomerates, varieties of limestone and sandstone etc., which may be quarried or split with crow bars, also including any rock which in dry state may be hard, requiring blasting but which, when wet, becomes soft and manageable by means other than blasting;

jj) macadam surfaces such as water bound and bitumen/tar bound; soling or roads, paths, etc. and hard core; compact moorum or stabilized soil requiring grafting tool or pick or both and shovel, closely applied; gravel and cobble stone

iii) lime concrete, stone masonry in lime mortar and brick work in lime/cement mortar below ground level, reinforced cement concrete which may be broken up with crow bars or picks and stone masonry in cement mortar below ground level; and

iv) boulders which do not require blasting found lying loose on the surface or embedded in river bed, soil, talus, slope wash and terrace material or dissimilar origin.

c) Hard Rock (requiring blasting)

This shall comprise :

i) any rock or cement concrete for the excavation of which the use of mechanical plant and/or blasting is required,

ii) reinforced cement concrete (reinforcement cut through but not separated from the concrete) below ground level; and

iii) boulders requiring blasting.

d) Hard Rock (using controlled blasting) : Hard rock requiring blasting as described under (d) but where controlled blasting is to be caried out locations where built-up area, huts, abodes of people and livestock at within 200 m.

e) Hard Rock (blasting prohibited)

Hard rock requiring blasting as described under (d) but where blasting is prohibited for any reason like people living within 20 m of blast sites etc. and excavation has to be carried out by chiseling, wedging or any other agreed method.

f) Marshy soil

This shall include soils like soft clays and peats excavated below the original ground level of marshes and swamps and soils excavated from other areas requiring continuous pumping or bailing out of water.

301.2.2 Authority for classification : The classification of excavation shall be decided by the Engineer and his decision shall be final and binding on the Contractor. Merely the use of explosives in excavation will not be considered as a reason for higher classification unless blasting is clearly necessary in the opinion of the Engineer.

301.3 Construction Operations

301.3.1 Setting out : After the site has been cleared as per Clause 200, the limits of excavation shall be set out true to lines, curves, slopes, grades and sections as shown on the drawings or as directed by the Engineer. The Contractor shall provide all labour, survey instruments and materials such as strings, pegs, nails, bamboos, stones, lime, mortar, concrete, etc., required in connection with the setting out of works and the establishment of bench marks. The Contractor shall be responsible for the maintenance of bench marks and other marks and stakes as long as in the opinion of the Engineer, they are required for the works.

301.3.2 Stripping and storing topsoil : When so directed by the Engineer, the topsoil existing over the sites of excavation shall be stripped to specified depths constituting Horizon "A" and stockpiled at designated locations for re-use in covering embankment slopes, cut slopes, berms and other disturbed areas where re-vegetation is desired. Prior to stripping the topsoil, all trees, shrubs etc. shall be removed along with their roots, with approval of the Engineer.

301.3.3 Excavation – General : All excavations shall be carried out in conformity with the directions laid here-in-under and in a manner approved by the Engineer. The work shall be so done that the suitable materials available from excavation are satisfactorily utilized as decided upon beforehand and suitable credit towards the cost of re-usable material and salvage value of unsuitable material shall be given by the Contractor while quoting the rates.

While planning or executing excavations, the Contractor shall take all adequate precautions against soil erosion, water pollution etc. as per Clause 306, and take appropriate drainage measures to keep the site free of water in accordance with Clause 311.

The excavations shall conform to the lines, grades, side slopes and levels shown on the drawings or as directed by the Engineer. The Contractor shall not excavate outside the limits of excavation. Subject to the permitted tolerances, any excess depth/width excavated beyond the specified levels/dimensions on the drawings shall be made good at the cost of the Contractor with suitable material of characteristics similar to that removed and compacted to the requirements of Clause 305.

All debris and loose material on the slopes of cuttings shall be removed. No backfilling shall be allowed to obtain required slopes excepting that when boulders or soft materials are encountered in cut slopes, these shall be excavated to approved depth on instructions of the Engineer and the resulting cavities filled with suitable material and thoroughly compacted in an appropriate manner.

After excavation, the sides of excavated area shall be trimmed and the area contoured to minimize erosion and ponding, allowing for natural drainage to take place.

301.3.4 Methods, tools and equipment : Only such methods, tools and equipment as approved by the Engineer shall be adopted/used in the work. If so desired by the Engineer, the Contractor shall demonstrate the efficacy of the type of equipment to be used before the commencement of work. Recommended equipments for different materials are indicated in Table 300-1.

Table 300-1 Recommended Equipment

Type of Excavation	Recommended equipments
Excavation in rock	Hydraulic excavator with rock breaker or Jack hammer operated with air compressor
Marsh excavation	Slurry pump and hydraulic excavator
Removal of earth	Hydraulic excavator
Small excavation	Backhoe loader
Areas where vibrations are prohibited	Silent cracking

301.3.5 **Rock excavation :** Rock, when encountered in road excavation, shall be removed upto the formation level or as otherwise indicated in the drawings. Where, however, unstable shales or other unsuitable materials are encountered at the formation level, these shall be excavated to the extent of 500 mm below the formation level or as otherwise specified. In all cases, the excavation operations shall be so carried out that at no point on cut formations the rock protrudes above the specified levels. Rocks and large boulders which are likely to cause differential settlement and also local drainage problems shall be removed to the extent of 500 mm below the formation level in the formation width including drains and cut through the side drain.

Where excavation is done to levels lower than those specified, the excess excavation shall be made good as per Clauses 301.3.3 and 301.6 to the satisfaction of the Engineer.

Slopes in rock cutting shall be finished to uniform lines corresponding to slope lines shown on the drawings or as directed by the Engineer. Notwithstanding the foregoing, all loose pieces of rock on excavated slope surface which move when pierced by a crowbar shall be removed.

Where blasting is to be resorted to, the same shall be carried out as per Clause 302 and all precautions indicated therein observed.

Where presplitting is prescribed to be done for the establishment of a specified slope in rock excavation, the same shall be carried out as per Clause 303.

301.3.6 **Marsh excavation :** The excavation of soil from marshes/swamps shall be carried out as per the programme approved by the Engineer.

Excavation of marshes shall begin at one end and proceed in one direction across the entire marsh immediately ahead of backfilling with materials like boulders, sand moorum, bricks bats, dismantled concrete as approved by the Engineer. The method and sequence of excavating and backfilling shall be such as to ensure, to the extent practicable, the

complete removal or displacement of all muck from within the lateral limits called for on the drawings or as staked by the Engineer.

301.3.7 Excavation of road shoulders/verge/median for widening of pavement or providing treated shoulders : In the works involving widening of existing pavements or providing paved shoulders, the existing shoulders/verge/median shall be removed to its full width and upto top of the subgrade. The subgrade material within 0.5 m from the lowest part of the pavement crust for the widened portion or paved shoulders shall be loosened and recompacted as per Clause 305. Any unsuitable material found in its portion shall be removed and replaced with the suitable material. While doing so, care shall be taken to see that no portion of the existing pavement designated for retention is loosened or disturbed. If the existing pavement gets disturbed or loosened, it shall be dismantled and cut to a regular shape with sides vertical and the disturbed/loosened portion removed completely and relaid as directed by the Engineer, at the cost of the Contractor.

301.3.8 Excavation for surface/sub-surface drains : Where the Contract provides for construction of surface/sub-surface drains, the same shall be done as per Clause 309. Excavation for these drains shall be carried out in proper sequence with other works as approved by the Engineer.

301.3.9 Slides : If slips, slides, over-breaks or subsidence occur in cuttings during the process of construction, they shall be removed at the cost of the Contractor as ordered by the Engineer. Adequate precautions shall be taken to ensure that during construction, the slopes are not rendered unstable or give rise to recurrent slides after construction. If finished slopes slide into the roadway subsequently, such slides shall be removed and paid for at the Contract rate for the class of excavation involved, provided the slides are not due to any negligence on the part of the Contractor. The classification of the debris material from the slips, slides etc. shall conform to its condition at the time of removal and payment made accordingly regardless of its condition earlier.

301.3.10 Dewatering : If water is met with in the excavations due to springs, seepage, rain or other causes, it shall be removed by suitable diversions, pumping or bailing out and the excavation kept dry whenever so required or directed by the Engineer. Care shall be taken to discharge the drained water into suitable outlets as not to cause damage to the works, crops or any other property. Due to any negligence on the part of the Contractor, if any such damage is caused, it shall be the sole responsibility of the Contractor to repair/restore to the original condition at his own cost or compensate for the damage.

301.3.11 Disposal of excavated materials : All the excavated materials shall either be reused with the approval of the Engineer or disposed off with all leads and lights as directed by the Engineer. Rates quoted by the Contractor deemed to include credit for usable material and salvage value of unusable materials.

301.3.12 Backfilling : Backfilling of masonry/concrete hume pipe drain excavation shall be done with approved material with all lifts and leads after concrete/masonry/hume pipe is fully set and carried out in such a way as not to cause undue thrust on any part of the structure and/or not to cause differential settlement. All space between the drain walls and the side of the excavation shall be refilled to the original surface making due allowance for settlement, in layers generally not exceeding 150 mm compacted thickness to the required density, using suitable compaction equipment such as trench compactor, mechanical tamper, rammer or plate compactor as directed by the Engineer.

301.4 Plying of Construction Traffic

Construction traffic shall not use the cut formation and finished subgrade without the prior permission of the Engineer. Any damage arising out of such use shall be made good by the Contractor at his own cost.

301.5 Preservation of Property

The Contractor shall undertake all reasonable precautions for the protection and preservation of any or all existing roadside trees, drains, sewers, sub-surface drains, pipes, conduits and any other structures under or above ground, which may be affected by construction operations and which, in the opinion of the Engineer, shall be continued in use without any change. Safety measures taken by the Contractor in this respect, shall be got approved from the Engineer. However, if any, of these objects is damaged by reason of the Contractor's negligence, it shall be replaced or restored to the original condition at his cost. If the Contractor fails to do so, within the required time as directed by the Engineer or if, in the opinion of the Engineer, the actions initiated by the Contractor to replace/ restore the damaged objects are not satisfactory, the Engineer shall arrange the replacement/restoration directly through any other agency at the risk and cost of the Contractor after issuing prior notice to the effect.

301.6 Preparation of Cut Formation

The cut formation, which serves as a sub-grade, shall be prepared to receive the sub-base/base course as directed by the Engineer.

Where the material in the subgrade (i.e. within 500 mm from the lowest level of the pavement crust) has a density less than specified in Table 300-3, the same shall be loosened to a depth of 500 mm and compacted in layers in accordance with the requirements of Clause 305. Any unsuitable material encountered in the subgrade level shall be removed as directed by the Engineer, replaced with suitable material and compacted in accordance with Clause 305.

In rocky formations, the surface irregularities shall be corrected and the levels brought up to the specified elevation with granular base material as directed by the Engineer, laid and compacted in accordance with the respective Specifications for these materials. The unsuitable material shall be disposed of in accordance with Clause 301.3.11. After satisfying the density requirements, the cut formation shall be prepared to receive the sub-base/ base course in accordance with Clauses 310 and 311.

301.7 Finishing Operations

Finishing operations shall include the work of properly shaping and dressing all excavated surfaces.

When completed, no point on the slopes shall vary from the designated slopes by more than 150 mm measured at right angles to the slope, except where excavation is in rock (hard or soft) where no point shall vary more than 300 mm from the designated slope. In no case shall any portion of the slope encroach on the roadway.

The finished cut formation shall satisfy the surface tolerances described in Clause 902.

Where feasible and directed, the topsoil removed earlier and conserved (Clauses 301.3.2 and 305.3.3) shall be spread over cut slopes, berms and other disturbed areas. Slopes may be roughened and moistened slightly, prior to the application of topsoil, in order to provide satisfactory bond. The depth of topsoil shall be sufficient to sustain plant growth, the usual thickness being from 75 mm to 100 mm.

301.8 Measurements for Payment

Excavation for roadway shall be measured by taking cross-sections at suitable intervals before the excavation starts (after clearing and grubbing/stripping etc. as the case may be) and after its completion and computing the volumes in cu.m by the method of average end areas for each class of material encountered. Where it is not feasible to compute volumes by this method because of erratic location of isolated deposits, the volumes shall be computed by other accepted methods.

At the option of the Engineer, the Contractor shall leave depth indicators during excavations of such shape and size and in such positions as directed so as to indicate the original ground level as accurately as possible. The Contractor shall see that these remain intact till the final measurements are taken.

For rock excavation, the overburden shall be removed first so that necessary cross-sections could be taken for measurement. Where cross-sectional measurements could not be taken due to irregular configuration or where the rock is admixed with other classes of

materials, the volumes shall be computed on the basis of stacks of excavated rubble after making 35 percent deduction therefrom. When volumes are calculated in this manner for excavated material other than rock, deduction made will be to the extent of 16 percent of stacked volumes.

Works involved in the preparation of cut formation shall be measured in units indicated below:

i)	Loosening and recompacting the loosened material at subgrade	…cu.m
ii)	Loosening and removal of unsuitable material and replacing with suitable material and compacting to required density	… cu.m
iii)	Preparing rocky subgrade	… cu.m
iv)	Stripping including storing and reapplication of topsoil	… cu.m

301.9 Rates

301.9.1 The Contract unit rates for the items of roadway and drain excavation shall be payment in full for carrying out the operations required for the individual items including full compensation for:

i) setting out;

ii) transporting the excavated materials for re-use or disposal with all leads and lifts by giving suitable credit towards the cost of re-usable material and salvage value of unusable material;

iii) trimming bottoms and slopes of excavation;

iv) dewatering;

v) keeping the work free of water as per Clause 311;

vi) arranging disposal sites; and

vii) all labour, materials, tools, equipment., safety measures, testing and incidentals necessary to complete the work to Specifications.

Provided, however, where presplitting is prescribed to achieve a specified slope in rock excavation, the same shall be paid for vide Clause 303.5.

301.9.2 The Contract unit rate for loosening and recompacting the loosened materials at subgrade shall include full compensation for loosening to the specified depth, including

breaking clods, spreading in layers, watering where necessary and compacting to the requirements.

301.9.3 Clauses 301.9.1 and 305.8 shall apply as regards Contract unit rate for item of removal of unsuitable material and replacement with suitable material respectively.

301.9.4 The Contract unit rate for item of preparing rocky sub-grade as per Clause 301.6 shall be full compensation for providing, laying and compacting granular base material for correcting surface irregularities including all materials, labour and incidentals necessary to complete the work and all leads and lifts.

301.9.5 The Contract unit rate for the items of stripping and storing topsoil and of reapplication of topsoil shall include full compensation for all the necessary operations including all lifts and leads.

302 BLASTING OPERATIONS

302.1 General

Blasting shall be carried out in a manner that completes the excavation to the lines indicated in drawings, with the least disturbance to adjacent material. It shall be done only with the written permission of the Engineer. All the statutory laws, regulations, rules, etc., pertaining to the acquisition, transportation, storage, handling and use of explosives shall be strictly followed by the Contractor.

The Contractor may adopt any method or methods of blasting consistent with the safety and job requirements. Prior to starting any phase of the operation, the Contractor shall provide information describing pertinent blasting procedures, dimensions and notes.

The magazine for the storage of explosives shall be built to the designs and specifications of the Explosives Department concerned and located at the approved site. No unauthorized person shall be admitted into the magazine which, when not in use, shall be kept securely locked. No matches or inflammable material shall be allowed in the magazine. The magazine shall have an effective lightning conductor. The following shall be hung in the lobby of the magazine:

a) A copy of the relevant rules regarding safe storage both in English and in the language with which the workers concerned are familiar,

b) A statement of up-to-date stock in the magazine,

c) A certificate showing the last date of testing of the lightning conductor, and

d) A notice that smoking is strictly prohibited.

All explosives shall be stored in a secure manner in compliance with all laws and ordinances, and all such storage places shall be marked. Where no local laws or ordinances apply, storage shall be provided to the satisfaction of the Engineer and in general not closer than 300 m from the road or from any building or camping area or place of human occupancy. In addition to these, the Contractor shall also observe the following instructions and any further additional instructions which may be given by the Engineer and shall be responsible for damage to property and any accident which may occur to workmen or public on account of any operations connected with the storage, handling or use of explosives and blasting. The Engineer shall frequently check the Contractor's compliance with these precautions.

302.2 Materials, Tools and Equipment

All the materials, tools and equipment used for blasting operations shall be of approved type. The Engineer may specify the type of explosives to be allowed in special cases. The fuse to be used in wet locations shall be sufficiently water-resistant as to be unaffected when immersed in water for 30 minutes. The rate of burning of the fuse shall be uniform and definitely known to permit such a length being cut as will permit sufficient time to the firer to reach safely before explosion takes place. Detonators shall be capable of giving effective blasting of the explosives. The blasting powder, explosives, detonators, fuses, etc., shall be fresh and not damaged due to dampness, moisture or any other cause. They shall be inspected before use and damaged articles shall be discarded totally and removed from the site immediately.

302.3 Personnel

The blasting operation shall remain in the charge of competent and experienced supervisor and workmen who are thoroughly acquainted with the details of handling explosives and blasting operations.

302.4 Blasting Operations

The blasting shall be carried out during the pre-determined hours of the day preferably during the mid-day luncheon hour or at the close of the work as ordered in writing by the Engineer. The hours shall be made known to the people in the vicinity.

The Contractor shall notify each public utility company having structures in proximity to the site of the work of his intention to use explosives. Such notice shall be given sufficiently in advance to enable the companies to take such steps as they may deem necessary to protect their property from injury. In advance of any blasting work within 50 m of any railway track or structures, the Contractor shall notify the concerned Railway Authority of the location, date, time and approximate duration of such blasting operation.

Red danger flags shall be displayed prominently in all directions during the blasting operations. The flags shall be planted 200 m from the blasting site in all directions. People, except those who actually light the fuse, shall be prohibited from entering this area and all persons including workmen shall be kept away from the flagged area, and all persons including workmen shall be removed from the flagged area at least 10 minutes before the firing. A warning siren shall be sounded for the above purpose.

Only controlled blasting shall be resorted to along with the safeguard above at locations where built-up area, huts, abodes of people and livestock lie within 200 m. Similarly excavation of hard rock without blasting is mandatory where people live within 20 m of blast site.

The charge holes shall be drilled to required depths and at suitable places. Blasting should be as light as possible consistent with thorough breakage of the material necessary for economic loading and hauling. Any method of blasting which leads to overshooting shall be discontinued.

When blasting is done with powder, the fuse cut to the required length shall be inserted into the hole and the powder dropped shall be gently tamped with copper roads with rounded ends. The explosive powder shall then be covered with tamping material which shall be tamped lightly but firmly.

When blasting is done with dynamite and other high explosives, dynamite cartridges shall be prepared by inserting the square cut end of a fuse into the detonator and finishing it with nippers at the open end, the detonator gently pushed into the primer leaving 1/3rd of the copper tube exposed outside. The paper of the cartridge shall then be closed up and securely bound with wire or twine. The primer shall be housed into the explosive. Boreholes shall be cleared of all debris and explosives inserted. The space of about 200 mm above the charge shall then be gently filled with dry clay, pressed home and the rest of the tamping formed of any convenient material gently packed with a wooden rammer.

At a time not more than 10 such charges will be prepared and fired. The man in charge shall blow a siren in a recognized manner for cautioning the people. All the people shall then be required to move to safe distances. The charges shall be lighted by the man-in-charge only. The man-in-charge shall count the number of explosions. He shall satisfy himself that all the charges have been exploded before allowing the workmen to go back to the work site.

After blasting operation, the Contractor shall compact the loose residual material below subgrade and replace the material removed below subgrade with suitable material.

302.5 Misfire

In case of misfire, the following procedure shall be observed:

i) Sufficient time shall be allowed to account for the delayed blast. The man-in-charge shall inspect all the charges and determine the missed charge.

ii) If it is the blasting powder charge, it shall be completely flooded with water. A new hole shall be drilled at about 450 mm from the old hole and fired. This should blast the old charge. In case, it does not blast the old charge, the procedure shall be repeated till the old charge is blasted:

iii) In case of charges of gelignite, dynamite, etc., the man-in-charge shall gently remove the tamping and the primer with the detonator. A fresh detonator and primer shall then be used to blast the charge. Alternatively, the hole may be cleared of 300 mm of tamping and the direction then ascertained by placing a stick in the hole. Another hole may then be drilled 150 mm away and parallel to it. This hole shall then be charged and fired when the misfired hole should explode at the same time. The man-in-charge shall at once report to the Contractor's office and the Engineer all cases of misfire, the cause of the same and what steps were taken in connection therewith.

If a misfire has been found to be due to defective detonator or dynamite, the whole quantity in the box from which defective article was taken must be sent to the authority directed by the Engineer for inspection to ascertain whether all the remaining materials in the box are also defective.

302.6 Account

A careful and day to day account of the explosive shall be maintained by the Contractor in an approved register and manner which shall be open to inspection by the Engineer at all times.

303 PRESPLITTING ROCK EXCAVATION SLOPES

303.1 General

Presplitting is defined as the establishment of a specified excavation slope in rock by the controlled use of explosives and blasting accessories in properly aligned and spaced drill holes.

The presplitting technique shall be used for forming rock excavation slopes at locations shown on the plans or as otherwise decided by the Engineer.

303.2 Construction Operations

Prior to starting drilling operations for presplitting, the Contractor shall furnish the Engineer a plan outlining the position of all drill holes, depth of drilling, type of explosives to be used, loading pattern and sequence of firing. The drilling and blasting plan is for record purposes only and will not absolve the Contractor of his responsibility for using proper drilling and blasting procedures. Controlled blasting shall begin with a short test section of a length approved by the Engineer. The test section shall be presplit, production drilled and blasted and sufficient material excavated whereby the Engineer can determine if the Contractor's method have produced an acceptable slope.

All overburden soil and weathered rock along the top of the excavation for a distance of about 5 to 15 m beyond the drilling limits, or to the end of the excavation, as decided by the Engineer shall be removed before drilling the presplitting holes. Particular care and attention shall be directed to the beginning and end of excavations to ensure complete removal of all overburden soil and weathered rock and to expose fresh rock to an elevation equal to the bottom of the adjacent lift of the presplitting holes being drilled.

Slope holes for presplitting shall be drilled along the line of the planned slope within the specified tolerances. The drill holes shall not be less than 60 mm nor more than 75 mm in diameter. Drilling operations shall be controlled by the use of proper equipment and technique to ensure that no hole shall deviate from the plane of the planned slope by more than 300 mm nor shall any hole deviate from being parallel to an adjacent hole by more than two-third of the planned horizontal spacing between holes.

The length of presplit holes for any individual lift shall not exceed 9 m.

The spacing of presplit holes shall not exceed 900 mm on centres and shall be adjusted to result in a uniform shear face between holes.

Auxiliary drill holes along the presplit line, not loaded or stemmed, may be ordered by the Engineer. Except for spacing, auxiliary drill holes shall conform to the provisions for presplit holes.

The line of production holes shall be placed inside the presplit lines in such a manner as to avoid damage to the presplit face.

If necessary, to reduce shatter and overbreak of the presplit surface, the first line of the production holes shall be drilled parallel to the slope line at the top of the cut and at each bench level thereafter.

Any blasting technique, which results in damage to the presplit surface, shall be immediately discontinued.

No portion of any production holes shall be drilled within 2.5 m of a presplit plane except as approved by the Engineer. The bottom of the production holes shall not be lower than the bottom of the presplit holes.

A maximum offset of 600 mm will be permitted for a construction working bench at the bottom of each lift for use in drilling the next lower presplitting pattern. The drilling operations shall be adjusted to compensate for drift of previous levels and for the offset at the start of new levels to maintain the specified slope plane.

The maximum diametre of explosives used in presplit holes shall not be greater than one-half the diameter of the presplit hole.

Only standard cartridge explosives prepared and packaged by explosive manufacturing firms shall be used in presplit holes. These shall be fired as recommended by the manufacturer. Ammonium nitrate composition blasting agents will not be permitted in presplitting operations.

Stemming may be required to achieve a satisfactory presplit face. Stemming material shall be dry free-running material all of which passes 11.2 mm sieve and 90 percent of which is retained on 2.80 mm sieve. Stemmed presplit holes shall be completely filled to the collar.

All charges in each presplitting pattern shall be detonated simultaneously.

303.3 Tolerances

The presplit face shall not deviate more than 300 mm from the plane passing through adjacent drill holes, except where the character of the rock is such that, as determined by the Engineer, irregularities are unavoidable. When completed, the average plane of the slopes shall conform to the slopes indicated on the plans and no point on the completed slopes shall vary from the designated slopes by more than 300 mm. These tolerances shall be measured perpendicular to the plane of the slope. In no case shall any portion of the slope encroach on the side drains.

As long as equally satisfactory presplit slopes are obtained, then either the slope face may be presplit before drilling for production blasting or presplitting the slope face and production blasting may be done at the same time, provided that the presplitting drill holes are fired with zero delay and the production holes are delayed starting at the row of holes farthest from the slope and progressing in steps to the row of holes nearest the presplit lines, which row shall be delayed at least 50 milliseconds. In either case the presplitting holes shall extend either to the end of the excavation or for a distance of not less than 15 m beyond the limits of the production holes to be detonated.

303.4 Measurements for Payment

The area of presplitting to be paid for, will be measured as square metres of acceptable presplit slope surface.

303.5 Rates

The Contract unit rate for presplitting work shall be payment in full for carrying out the required operations for obtaining acceptable presplit slope surfaces. The quantity of rock excavated through the production/presplit holes shall be paid for as per Clause 301.9.1.

304 EXCAVATION FOR STRUCTURES

304.1 Scope

Excavation for structures shall consist of the removal of material for the construction of foundations for bridges, culverts, retaining walls, headwalls, cutoff walls, pipe culverts and other similar structures, in accordance with the requirements of these Specifications and the lines and dimensions shown on the drawings or as indicated by the Engineer. The work shall include construction of the necessary cofferdams and cribs and their subsequent removal; all necessary sheeting, shoring, bracing, draining and pumping; the removal of all logs, stumps, grubs and other deleterious matter and obstruction, necessary for placing the foundations; trimming bottoms of excavations; backfilling and clearing up the site and the disposal of all surplus material.

304.2 Classification of Excavation

All materials involved in excavation shall be classified in accordance with Clause 301.2.

304.3 Construction Operations

304.3.1 Setting out : After the site has been cleared according to Clause 201, the limits of excavation shall be set out true to lines, curves and slopes to Clause 301.3.1.

304.3.2 Excavation : Excavation shall be taken to the width of the lowest step of the footing and the sides shall be left plumb where the nature of soil allows it. Where the nature of soil or the depth of the trench and season of the year do not permit vertical sides, the Contractor at his own cost shall put up necessary shoring, strutting and planking or cut slopes to a safer angle or both with due regard to the safety of personnel and works and to the satisfaction of the Engineer.

The depth to which the excavation is to be carried out shall be as shown on the drawings, unless the type of material encountered is such as to require changes, in which case the

depth shall be as ordered by the Engineer. Propping shall be undertaken when any foundation or stressed zone from an adjoining structure is within a line of 1 vertical to 2 horizontal from the bottom of the excavation.

Where blasting is to be resorted, the same shall be carried out in accordance with Clause 302 and all precautions indicated therein observed. Where blasting is likely to endanger adjoining foundations or other structures, necessary precautions such as controlled blasting, providing rubber mat cover to prevent flying of debris etc. shall be taken to prevent any damage.

304.3.3 Dewatering and protection : Normally, open foundations shall be laid dry. Where water is met with in excavation due to stream flow, seepage, springs, rain or other reasons, the Contractor shall take adequate measures such as bailing, pumping, constructing diversion channels, drainage channels, bunds, depression of water level by well-point system, cofferdams and other necessary works to keep the foundation trenches dry when so required and to protect the green concrete/masonry against damage by erosion or sudden rising of water level. The methods to be adopted in this regard and other details thereof shall be left to the choice of the Contractor but subject to the approval of the Engineer. Approval of the Engineer shall, however, not relieve the Contractor of the responsibility for the adequacy of dewatering and protection arrangements for the quality and safety of the works.

Where cofferdams are required, these shall be carried to adequate depths and heights, be safely designed and constructed and be made as watertight as is necessary for facilitating construction to be carried out inside them. The interior dimensions of the cofferdams shall be such as to give sufficient clearance for the construction and inspection and to permit installation of pumping equipments, etc., inside the enclosed area.

If it is determined beforehand that the foundations cannot be laid dry or the situation is found that the percolation is too heavy for keeping the foundation dry, the foundation concrete shall be laid under water by tremie pipe only. In case of flowing water or artesian springs, the flow shall be stopped or reduced as far as possible at the time of placing the concrete.

Pumping from the interior of any foundation enclosure shall be done in such a manner as to preclude the possibility of the movement of water through any fresh concrete. No pumping shall be permitted during the placing of concrete and for a period of at least 24 hours thereafter, unless it is done from a suitable sump separated from the concrete work by a watertight wall or other similar means.

At the discretion of the Contractor, cement grouting or other approved methods may be used to prevent or reduce seepage and to protect the excavation area.

The Contractor shall take all precautions in diverting channels and in discharging the drained water as not to cause damage to the works, crops or any other property.

304.3.4 Preparation of foundation : The bottom of the foundation shall be levelled both longitudinally and transversely or stepped as directed by the Engineer. Before footing is laid, the surface shall be slightly watered and rammed. In the event of excavation having been made deeper than that shown on the drawings or as otherwise ordered by the Engineer, the extra depth shall be made up with concrete or masonry of the foundation at the cost of the Contractor as per Clause 2104.1. Ordinary filling shall not be used for the purpose to bring the foundation to level.

When rock or other hard strata is encountered, it shall be freed of all soft and loose material, cleaned and cut to a firm surface either level or stepped as directed by the Engineer. All seams shall be cleaned out and filled with cement mortar or grout to the satisfaction of the Engineer. In the case of excavation in rock, annular space around footing shall be filled with lean concrete M 15 upto the top level of rock.

If the depth of fill required is more than 1.5 m above the top of the footing, filling upto 1.5 m above top of footing shall be done with lean concrete M 15 followed by boulders grouted with cement.

When foundation piles are used, the excavation of each pit shall be substantially completed before beginning pile-driving operations therein. After pile driving operations in a given pit are completed, all loose and displaced materials therein shall be removed to the elevation of the bottom of the footings.

304.3.5 Slips and slip-outs : If there are any slips or slip-outs in the excavation, these shall be removed by the Contractor at his own cost.

304.3.6 Public safety : Near towns, villages and all frequented places, trenches and foundation pits shall be securely fenced, provided with proper caution signs and marked with red lights at night to avoid accidents. The Contractor shall take adequate protective measures to see that the excavation operations do not affect or damage adjoining structures. For safety precautions, guidance may be taken from IS:3764.

304.3.7 Backfilling : Backfilling shall be done with approved material after concrete or masonry is fully set and carried out in such a way as not to cause undue thrust on any part of the structure. All space between foundation masonry or concrete and the sides of excavation shall be refilled to the original surface in layers not exceeding 150 mm compacted thickness. The compaction shall be done with the help of suitable equipment such as trench compactor, mechanical tamper, rammer, plate vibrator etc., after necessary watering, so as to achieve a density not less than the field density before excavation.

304.3.8 Disposal of surplus excavated materials : Clause 301.3.11 shall apply.

304.4 Measurements for Payment

Excavation for structures shall be measured in cu.m for each class of material encountered, limited to the dimensions shown on the drawings or as directed by the Engineer. Excavation over increased width, cutting of slopes, production/support to the existing structures shoring, shuttering and planking shall be deemed as convenience for the Contractor in executing the work and shall not be measured and paid separately.

Preparation of rock foundation shall be measured in square metres. Foundation sealing, dewatering, including pumping shall be deemed to be incidental to the work unless separate provision is made for in the Contract. In the latter case, payment shall be on lumpsum basis as provided in the Bill of Quantities.

304.5 Rates

304.5.1 The Contract unit rate for the items of excavation for structures shall be payment in full for carrying out the required operations including full compensation for:

i) setting out;

ii) construction of necessary cofferdams, cribs\sheeting, shoring and bracing and their subsequent removal;

iii) removal of all logs, stumps, grubs and other deleterious matter and obstructions, for placing the foundations including trimming of bottoms of excavations;

iv) foundation sealing, dewatering including pumping when no separate provision for it is made in the Contract:

v) backfilling, clearing up the site and disposal of all surplus material with all lifts and leads or as otherwise specified; and

vi) all labour, materials, tools, equipment, safety measures, diversion of traffic and incidentals necessary to complete the work to Specifications.

304.5.2 The Contract unit rate for preparation of rock foundation shall be full compensation for cutting, trimming and cleaning the foundation surface and filling/sealing of all seams with cement grout or mortar including all materials, labour and incidentals required for completing the work.

305 EMABANKMENT CONSTRUCTION

305.1 General

305.1.1 Description : These Specifications shall apply to the construction of embankments including sub-grades, earthen shoulders and miscellaneous backfills with approved material obtained from approved source, including material from roadway and drain excavation, borrow pits or other sources. All embankments sub-grades, earthen shoulders and miscellaneous backfills shall be constructed in accordance with the requirements of these Specifications and in conformity with the lines, grades, and cross-sections shown on the drawings or as directed by the Engineer.

305.2 Materials and General Requirements

305.2.1 Physical requirements

305.2.1.1 The materials used in embankments, subgrades, earthen shoulders and miscellaneous backfills shall be soil, moorum, gravel, pond ash, a mixture of these or any other material approved by the Engineer. Such materials shall be free of logs, stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of the embankment/sub-grade. The use of pond ash as fill material shall be mandatory in road/ flyover embankment construction in the areas where pond ash is available in adequate quantities within economical viable lead in accordance with the guidelines of IRC:SP:58-2001 unless it is not considered viable by the Chief Engineer/Engineer in Chief or any other Engineering Officer of equivalent rank.

The following types of material shall be considered unsuitable for embankment:

a) Materials from swamps, marshes and bogs;

b) Peat, log, stump and perishable material; any soil that classifies as OL, OI, OH or Pt in accordance with IS:1498;

c) Materials susceptible to spontaneous combustion;

d) Materials in a frozen condition;

e) Clay having liquid limit exceeding 50 and plasticity index exceeding 25; and

f) Materials with salts resulting in leaching in the embankment.

305.2.1.2 Expansive clay exhibiting marked swell and shrinkage properties ("free swelling index" exceeding 50 percent when tested as per IS:2720 – Part 40) shall not be used as a fill material. Where an expansive clay having "free swelling index" value less than 50 percent is used as a fill material, subgrade and top 500 mm portion of the embankment just below sub-grade shall be non-expansive in nature.

305.2.1.3 Any fill material with a soluble sulphate content exceeding 1.9 grams of sulphate (expressed as SO_3) per litre when tested in accordance with BS:1377 Test 10, but using a 2:1 water-soil ratio shall not be deposited within 500 mm distance(or any other distance described in the Contract), of permanent works constructed out of concrete, cement bound materials or other cementitious material..

Materials with a total sulphate content (expressed as SO_3) exceeding 0.5 percent by mass, when tested in accordance with BS:1377 Test 9 shall not be deposited within 500 mm, or other distances described in the Contract, of metallic items forming part of the Permanent Works.

305.2.1.4 The size of the coarse material in the mixture of earth shall ordinarily not exceed 75 mm when placed in the embankment and 50 mm when placed in the sub-grade. However, the Engineer may at his discretion permit the use of material coarser than this also if he is satisfied that the same will not present any difficulty as regards the placement of fill material and its compaction to the requirements of these Specifications. The maximum particle size in such cases, however, shall not be more than two-thirds of the compacted layer thickness.

305.2.1.5 Ordinarily, only the materials satisfying the density requirements given in Table 300-2 shall be employed for the construction of the embankment and the sub-grade.

Table 300-2 Density Requirements of Embankment and Sub-grade Materials

S.No.	Type of Work	Maximum laboratory dry unit weight when tested as per IS:2720 (Part 8)
1.	Embankments up to 3 m height, not subjected to extensive flooding	Not less than 16 kN/cu.m
2.	Embankments exceeding 3 m height or embankments of any height subject to long periods of inundation	Not less than 17 kN/ cu.m
3.	Subgrade and earthen shoulders/verges/backfill	Not less than 18 kN/cu.m

Notes: 1) This Table is not applicable for lightweight fill material, e.g., cinder, pond ash, etc.

2) The Engineer may relax these requirements at his discretion taking into account the availability of materials for construction and other relevant factors.

3) The material to be used in subgrade should also satisfy design CBR at the dry unit weight applicable as per Table 300-3.

305.2.2 General requirements

305.2.2.1 The materials for embankment shall be obtained from approved sources with preference given to acceptable materials becoming available from nearby roadway excavation under the same Contract.

The work shall be so planned and executed that the best available materials are saved for the subgrade and the embankment portion just below the subgrade.

305.2.2.2 Borrow materials : No borrow area shall be made available by the Employer. The arrangement for the source of supply of the material for embankment and sub-grade complying with the guidelines as well as compliance to environmental requirements in respect of excavation and borrow areas as stipulated, from time to time by the Ministry of Environment and Forests, Government of India and the local bodies, as applicable shall be the sole responsibility of the Contractor.

Area where pond ash is available for construction of embankment, borrowing of the earth shall be avoided to the extent possible. Embankment constructed out of pond ash shall be properly designed to ensure stability against uplifting etc. A suitable thick cover may preferably be provided at intervening layers of pond ash for this purpose. A thick soil cover shall bind the edge of the embankment to protect it against erosion. Minimum thickness of such soil cover shall be 500 mm.

Borrow pits along the road shall be discouraged. If permitted by the Engineer, these shall not be dug continuously. Ridges of not less than 8 m width should be left at intervals not exceeding 300 m. Small drains shall be cut through the ridges to facilitate drainage. The depth of the pits shall be so regulated that their bottom does not cut an imaginary line having a slope of 1 vertical to 4 horizontal projected from the edge of the final section of the bank, the maximum depth in any case being limited to 1.5 m. Also, no pit shall be dug within the offset width from the toe of the embankment required as per the consideration of stability with a minimum width of 10 m.

Haulage of material to embankments or other areas of fill shall proceed only when sufficient spreading and compaction plant is operating at the place of deposition.

Where the excavation reveals a combination of acceptable and unacceptable materials, the Contractor shall, unless otherwise agreed by the Engineer, carry out the excavation in such a manner that the acceptable materials are excavated separately for use in the permanent works without contamination by the unacceptable materials. The acceptable materials shall be stockpiled separately.

The Contractor shall ensure that he does not adversely affect the stability of excavation or fills by the methods of stockpiling materials, use of plants or siting of temporary buildings or structures.

The Contractor shall obtain representative samples from each of the identified borrow areas and have these tested at the site laboratory following a testing programme approved by the Engineer. It shall be ensured that the subgrade material when compacted to the density requirements as in Table 300-3 shall yield the design CBR value of the sub-grade.

Table 300-3 Compaction Requirements for Embankment and Sub-grade

Type of work/material	Relative compaction as percentage of max. laboratory dry density as per IS:2720 (Part 8)	Minimum CBR %
1. Subgrade and earthen shoulders	Not less than 98%	5
2. Embankment	Not less than 97%	5
3. Expansive Clays		
a) Subgrade and 500 mm portion just below the sub-grade	Not allowed	-
b) Remaining portion of embankment	Not less than 90%	4

In case the sub-grade CBR is less than the specified in the Table 300-3, the subgrade shell be stablised with line, cement or any other stablizer accredited by IRC or by mechanical stablization so as to raise the (Field) CBR is not less than15 percent.

The Contractor shall at least 7 working days before commencement of compaction submit the following to the Engineer for approval:

i) The values of maximum dry density and optimum moisture content obtained in accordance with IS:2720 (Part 8), appropriate for each of the fill materials he intends to use.

ii) A graph of density plotted against moisture content from which each of the values in (i) above of maximum dry density and optimum moisture content were determined.

Once the above information has been approved by the Engineer, it shall form the basis for compaction.

305.3 Construction Operations

305.3.1 Setting out : After the site has been cleared to Clause 201, the work shall be set out to Clause 301.3.1 The limits of embankment/sub-grade shall be marked by fixing batter pegs on both sides at regular intervals as guides before commencing the

earthwork. The embankment/sub-grade shall be built sufficiently wider than the design dimension so that surplus material may be trimmed, ensuring that the remaining material is to the desired density and in position specified and conforms to the specified side slopes.

305.3.2 Dewatering : If the foundation of the embankment is in an area with stagnant water, and in the opinion of the Engineer it is feasible to remove it, the same shall be removed by bailing out or pumping, as directed by the Engineer and the area of the embankment foundation shall be kept dry. Care shall be taken to discharge the drained water so as not to cause damage to the works, crops or any other property. Due to any negligence on the part of the Contractor, if any such damage is caused, it shall be the sole responsibility of the Contractor to repair/restore it to original condition or compensate the damage at his own cost.

If the embankment is to be constructed under water, Clause 305.4.6 shall apply.

305.3.3 Stripping and storing topsoil : In localities where most of the available embankment materials are not conducive to plant growth, or when so directed by the Engineer, the topsoil from all areas of cutting and from all areas to be covered by embankment foundation shall be stripped to specified depths not less than 150 mm and stored in stockpiles of height not exceeding 2 m for covering embankment slopes, cut slopes and other disturbed areas where re-vegetation is desired. Topsoil shall not be unnecessarily trafficked either before stripping or when in a stockpile. Stockpiles shall not be surcharged or otherwise loaded and multiple handling shall be kept to a minimum.

305.3.4 Compacting ground supporting embankment/sub-grade: Where necessary, the original ground shall be leveled to facilitate placement of first layer of embankment, scarified, mixed with water and then compacted by rolling in accordance with Clauses 305.3.5 and 305.3.6 so as to achieve minimum dry density as given in Table 300-3.

In case where the difference between the sub-grade level (top of the sub-grade on which pavement rests) and ground level is less than 0.5 m and the ground does not have 98 percent relative compaction with respect to the dry density (as given in Table 300-3), the ground shall be loosened upto a level 0.5 m below the sub-grade level, watered and compacted in layers in accordance with Clauses 305.3.5 and 305.3.6 to achieve dry density not less than 98 percent relative compaction as given in Table 300-3.

Where so directed by the Engineer, any unsuitable material occurring in the embankment foundation (500 mm portion just below the sub-grade) shall be removed, suitably disposed and replaced by approved materials laid in layers to the required degree of compaction.

Any foundation treatment specified for embankments especially high embankments, resting on suspect foundations as revealed by borehole logs shall be carried out in a manner and to the depth as desired by the Engineer. Where the ground on which an embankment is to be built has any of such material types (a) to (f) in Clause 305.2.1.1 at least 500 mm of such material must be removed and replaced by acceptable fill material before embankment construction commences.

305.3.5 Spreading material in layers and bringing to appropriate moisture content

305.3.5.1 The embankment and sub-grade material shall be spread in layers of uniform thickness not exceeding 200 mm compacted thickness over the entire width of embankment by mechanical means, finished by a motor grader and compacted as per Clause 305.3.6. The motor grader blade shall have hydraulic control suitable for initial adjustment and maintain the same so as to achieve the specific slope and grade. Successive layers shall not be placed until the layer under construction has been thoroughly compacted to the specified requirements as in Table 300-3 and got approved by the Engineer. Each compacted layer shall be finished parallel to the final cross-section of the embankment.

305.3.5.2 Moisture content of the material shall be checked at the site of placement prior to commencement of compaction; if found to be out of agreed limits, the same shall be made good. Where water is required to be added in such constructions, water shall be sprinkled from a water tanker fitted with sprinkler capable of applying water uniformly with a controllable rate of flow to variable widths of surface but without any flooding. The water shall be added uniformly and thoroughly mixed in soil by blading, discing or harrowing until a uniform moisture content is obtained throughout the depth of the layer.

If the material delivered to the roadbed is too wet, it shall be dried, by aeration and exposure to the sun, till the moisture content is acceptable for compaction. Should circumstances arise, where owing to wet weather, the moisture content cannot be reduced to the required amount by the above procedure, compaction work shall be suspended.

Moisture content of each layer of soil shall be checked in accordance with IS:2720 (Part 2), and unless otherwise mentioned, shall be so adjusted, making due allowance for evaporation losses, that at the time of compaction it is in the range of 1 percent above to 2 percent below the optimum moisture content determined in accordance with IS:2720 (Part 8) as the case may be. Expansive clays shall, however, be compacted at moisture content corresponding to the specified dry density, but on the wet side of the optimum moisture content obtained from the laboratory compaction curve.

After adding the required amount of water, the soil shall be processed by means of graders, harrows, rotary mixers or as otherwise approved by the Engineer until the layer is uniformly wet.

Clods or hard lumps of earth shall be broken to have a maximum size of 75 mm when being placed in the embankment and a maximum size of 50 mm when being placed in the sub-grade.

305.3.5.3 Embankment and other areas of fill shall, unless otherwise required in the Contract or permitted by the Engineer, be constructed evenly over their full width and their fullest possible extent and the Contractor shall control and direct construction plant traffic shall be made good by the Contractor with material and other vehicular traffic uniformly over them. Damage by construction plant and other having the same characteristics and strength as the material had before it was damaged.

Embankments and other areas of unsupported fills shall not be constructed with steeper side slopes, or to greater widths than those shown in the Contract, except to permit adequate compaction at the edges before trimming back, or to obtain the final profile following any settlement of the fill and the underlying material,

Whenever fill is to be deposited against the face of a natural slope, or sloping earthworks face including embankments, cuttings, other fills and excavations steeper than 1 vertical to 4 horizontal, such faces shall be benched as per Clause 305.4.1 immediately before placing the subsequent fill.

All permanent faces of side slopes of embankments and other areas of fill shall, subsequent to any trimming operations, be reworked and sealed to the satisfaction of the Engineer by tracking a tracked vehicle, considered suitable by the Engineer, on the slope or any other method approved by the Engineer.

305.3.6 **Compaction :** Only the compaction equipment approved by the Engineer shall be employed to compact the different material types encountered during construction. Static three wheel roller, self propelled single drum vibratory roller, vibratory tandem roller, pneumatic tyred, pad foot rollers, etc., of suitable size and capacity as approved by the Engineer shall be used for the different types and grades of materials required to be compacted either individually or in suitable combinations.

The compaction shall be done with the help of self-propelled single drum vibratory roller or pad foot vibratory roller of 80 to 100 kN static weight or heavy pneumatic tyre roller of adequate capacity capable of achieving required compaction with nine wheels and 200 to 300 kN weight with minimum tyre pressure of 0.7 MPa. The Contractor shall demonstrate the efficacy of the equipment he intends to use by carrying out compaction trials. The procedure to be adopted for these site trials shall first be submitted to the Engineer for approval.

Earthmoving plant shall not be accepted as compaction equipment nor shall the use of a lighter category of plant to provide any preliminary compaction to assist the use of heavier plant be taken into account.

Each layer of the material shall be thoroughly compacted to the densities specified in Table 300-3. Subsequent layers shall be placed only after the finished layer has been tested according to Clause 903.2.2 and accepted by the Engineer. The Engineer may permit measurement of field dry density by a nuclear moisture/density gauge used in accordance with agreed procedure and the gauge is calibrated to provide results identical to that obtained from tests in accordance with IS:2720 (Part 28). A record of the same shall be maintained by the Contractor.

When density measurements reveal any soft areas in the embankment/sub-grade/earthen shoulders, further compaction shall be carried out as directed by the Engineer. If inspite of that the specified compaction is not achieved, the material in the soft areas shall be removed and replaced by approved material, compacted using appropriate mechanical means such as light weight vibratory roller, double drum walk behind roller, vibratory plate compactor, trench compactor or vibratory tamper to the density requirements and satisfaction of the Engineer.

305.3.7 Drainage : The surface of the embankment/sub-grade at all times during construction shall be maintained at such a crossfall (not flatter than that required for effective drainage of an earthen surface) as will shed water and prevent ponding.

305.3.8 Repairing of damages caused by rain/spillage of water : The soil in the affected portion shall be removed in such areas as directed by the Engineer before next layer is laid and refilled in layers and compacted using appropriate mechanical means such as small vibratory roller, plate compactor or power rammer to achieve the required density in accordance with Clause 305.3.6. If the cut is not sufficiently wide for use of required mechanical means for compaction, the same shall be widened suitably to permit their use for proper compaction. Tests shall be carried out as directed by the Engineer to ascertain the density requirements of the repaired area. The work of repairing the damages including widening of the cut, if any, shall be carried out by the Contractor at his own cost, including the arranging of machinery/equipment for the purpose.

305.3.9 Finishing operations : Finishing operations shall include the work of shaping and dressing the shoulders/verge/roadbed and side slopes to conform to the alignment, levels, cross-sections and dimensions shown on the drawings or as directed by the Engineer subject to the surface tolerance described in Clause 902. Both the upper and lower ends of the side slopes shall be rounded off to improve appearance and to merge the embankment with the adjacent terrain.

The topsoil, removed and conserved earlier (Clause 301.3.2 and 305.3.3) shall be spread over the fill slopes as per directions of the Engineer to facilitate the growth of vegetation. Slopes shall be roughened and moistened slightly prior to the application of the topsoil in order to provide satisfactory bond. The depth of the topsoil shall be sufficient to sustain plant growth, the usual thickness being from 75 mm to 150 mm.

Where directed, the slopes shall be turfed with sods in accordance with Clause 307. If seeding and mulching of slopes is prescribed, this shall be done to the requirements of Clause 308.

When earthwork operations have been substantially completed, the road area shall be cleared of all debris, and ugly scars in the construction area responsible for objectionable appearance eliminated.

305.4 Construction of Embankment and Subgrade under Special Conditions

305.4.1 Earthwork for widening existing road embankment : When an existing embankment and/or sub-grade is to be widened and its slopes are steeper than 1 vertical on 4 horizontal, continuous horizontal benches, each at least 300 mm wide, shall be cut into the old slope for ensuring adequate bond with the fresh embankment/sub-grade material to be added. The material obtained from cutting of benches could be utilized in the widening of the embankment / subgrade. However, when the existing slope against which the fresh material is to be placed is flatter than 1 vertical on 4 horizontal, the slope surface may only be ploughed or scarified instead of resorting to benching.

Where the width of the widened portions is insufficient to permit the use of conventional rollers, compaction shall be carried out with the help of light weight vibratory roller, double drum walk behind roller, vibratory plate compactor or vibratory tamper or any other appropriate equipment approved by the Engineer. End dumping of material from trucks for widening operations shall be avoided except in difficult circumstances when the extra width is too narrow to permit the movement of any other types of hauling equipment.

305.4.2 Earthwork for embankment and sub-grade to be placed against sloping ground : Where an embankment/subgrade is to be placed against sloping ground, the latter shall be appropriately benched or ploughed/scarified as required in Clause 305.4.1 before placing the embankment/sub-grade material. Extra earthwork involved in benching or due to ploughing/scarifying etc. shall be considered incidental to the work.

For wet conditions, benches with slightly inward fall and subsoil drains at the lowest point shall be provided as per the drawings, before the fill is placed against sloping ground.

Where the Contract requires construction of transverse subsurface drain at the cut-fill interface, work on the same shall be carried out to Clause 309 in proper sequence with the embankment and sub-grade work as approved by the Engineer.

305.4.3 Earthwork over existing road surface : Where the embankment is to be placed over an existing road surface, the work shall be carried out as indicated below:

i) If the existing road surface is of granular type and lies within 1 m of the new sub-grade level. The existing granular base/sub-base, as the case, may be, shall be scarified to a depth of 50 mm or as directed so as to provide ample bond between the old and new material ensuring that at least 500 mm portion below the top of new sub-grade level is compacted to the desired density;

ii) If the existing road surface is of bituminous type and lies within 1 m of the new sub-grade level, the bituminous layer shall be removed completely, so as to avoid presence of impermeable layer beneath the new thin earthen layer and also provide ample bond between the old and new material ensuring that at least 500 mm portion below the top of new subgrade level is compacted to the desired density;

iii) If the existing road surface is of cement concrete type and lies within 1 m of the new sub-grade level, the same shall be removed completely;

iv) If the level difference between the existing road surface and the new formation level is more than 1 m, the existing surface shall be permitted to stay in place without any modification.

305.4.4 Embankment and subgrade around structures : To avoid interference with the construction of abutments, wing walls or return walls of culvert/bridge structures, the Contractor shall, at points to be determined by the Engineer suspend work on embankment forming approaches to such structures, until such time as the construction of the latter is sufficiently advanced to permit the completion of approaches without the risk of damage to the structure.

Unless directed otherwise, the filling around culverts, bridges and other structures upto a distance of twice the height of the road from the back of the abutment shall be carried out independent of the work on the main embankment. The fill material shall not be placed against any abutment or wing wall, unless permission has been given by the Engineer but in any case not until the concrete or masonry has been in position for 14 days. The embankment and sub-grade shall be brought up simultaneously in equal layers on each side of the structure to avoid displacement and unequal pressure. The sequence of work in this regard shall be got approved from the Engineer.

The material used for backfill shall not be an organic soil or highly plastic clay having plasticity index and liquid limit more than 20 and 40 respectively when tested according to IS:2720 (Part 5). Filling behind abutments and wing walls for all structures shall conform to the general guidelines given in Appendix-6 of IRC:78 (Standard Specifications and Code of Practice for Road Bridges-Section VII) in respect of the type of material, the extent of

backfill, its laying and compaction etc. The fill material shall be deposited in horizontal layers in loose thickness and compacted thoroughly to the requirements of Table 300-3.

Where the provision of any filter medium is specified behind the abutment, the same shall be laid in layers simultaneously with the laying of fill material. The material used for filter shall conform to the requirements for filter medium spelt out in Clause 2502/309.3.2 (B) unless otherwise specified in the Contract.

Where it may be impracticable to use conventional rollers, the compaction shall be carried out by appropriate mechanical means such as small vibratory roller, plate compactor or power rammer. Care shall be taken to see that the compaction equipment does not hit or come too close to any structural member so as to cause any damage to them or excessive pressure against the structure.

305.4.5 Construction of embankment over ground incapable of supporting construction equipment : Where embankment is to be constructed across ground which will not support the weight of repeated heavy loads of construction equipment, the first layer of the fill may be constructed by placing successive loads of material in a uniformly distributed layer of a minimum thickness required to support the construction equipment as permitted by the Engineer. The Contractor, if so desired by him, may also use suitable geosynthetic material to increase the bearing capacity of the foundation. This exception to normal procedure will not be permitted where, in the opinion of the Engineer, the embankments could be constructed in the approved manner over such ground by the use of lighter or modified equipment after proper ditching and drainage have been provided. Where this exception is permitted, the selection of the material and the construction procedure to obtain an acceptable layer shall be the responsibility of the Contractor. The cost of providing suitable traffic conditions for construction equipment over any area of the Contract will be the responsibility of the Contractor and no extra payment will be made to him. The remainder of the embankment shall be constructed as specified in Clause 305.3.

305.4.6 Embankment construction under water : Where filling or backfilling is to be placed under water, only acceptable granular material or rock shall be used unless otherwise approved by the Engineer. Acceptable granular material shall be of GW, SW, GP, SP as per IS:1498 and consist of graded, hard durable particles with maximum particle size not exceeding 75 mm. The material should be non-plastic having uniformity coefficient of not less than 10. The material placed in open water shall be deposited by end tipping without compaction.

Coarse sand blanket layer in accordance with the provision of IRC:34 shall be made for construction of embankment in water logged and marshy areas.

305.4.7 Earthwork for high embankment : In the case of high embankments (more than 6 m), the Contractor shall normally use pond ash in conformity with Clause 305.2.1.1

or the material from the specified borrow area. In case, he desires to use different material for his own convenience, he shall have to carry out necessary soil investigations and redesign the high embankment at his own cost. The Contractor shall then furnish the soil test data and design of high embankment for approval of the Engineer, who reserves the right to accept or reject it.

If necessary, stage construction of fills and any controlled rates of filling shall be carried out in accordance with the Contract including installation of instruments and its monitoring.

Where required, the Contractor shall surcharge embankments or other areas of fill with approved material for the periods specified in the Contract. If settlement of surcharged fill results in any surcharging material, which is unacceptable for use in the fill being surcharged, lying below formation level, the Contractor shall remove the unacceptable material and dispose it as per direction of the Engineer. He shall then bring the resultant level up to formation level with acceptable material.

305.4.8. **Settlement period :** Where settlement period is specified in the Contract, the embankment shall remain in place for the required settlement period before excavating for abutment, wingwall, retaining wall, footings, etc., or driving foundation piles. The duration of the required settlement period at each location shall be as provided for in the Contract or as directed by the Engineer.

305.5 Plying of Traffic

Construction and other vehicular traffic shall not use the prepared surface of the embankment and/or sub-grade without the prior permission of the Engineer. Any damage arising out of such use shall, however, be made good by the Contractor at his own cost as directed by the Engineer.

305.6 Surface Finish and Quality Control of Work

The surface finish of construction of sub-grade shall conform to the requirements of Clause 902. Control on the quality of materials and works shall be exercised in accordance with Clause 903.

305.7 Sub-grade Strength

305.7.1 It shall be ensured prior to actual execution that the borrow area material to be used in the sub-grade satisfies the requirements of design CBR.

305.7.2 Sub-grade shall be compacted and finished to the design strength consistent with other physical requirements. The actual laboratory CBR values of constructed sub-

grade shall be determined on undisturbed samples cut out from the compacted sub-grade in CBR mould fitted with cutting shoe or on remoulded samples, compacted to the field density at the field moisture content.

305.8 Measurements for Payment

Each embankment/sub-grade construction shall be measured separately by taking cross sections at intervals given in sub-section 113.3 after completion of clearing and grubbing (not the virgin ground level) and after completion of embankment/sub-grade and computing the volumes of earthwork in cubic metres by the method of average end areas.

The measurement of fill material from borrow areas shall be the difference between the net quantities of compacted fill and the net quantities of suitable material brought from roadway and drainage excavation. For this purpose, it shall be assumed that one cu.m of suitable material brought to site from road and drainage excavation forms one cu.m of compacted fill and all bulking or shrinkage shall be ignored.

The embankment constructed out of pond ash with soil cover at intervening layer and at edge shall be measured in cu.m including soil cover volume. Construction of embankment under water shall be measured in cu.m.

Construction of high embankment with specified material and in specified manner shall be measured in cu.m.

Stripping including storing and reapplication of top soil shall be measured in cu.m.

Work involving loosening and recompacting of ground supporting embankment/subgrade shall be measured in cu.m.

Removal of unsuitable material at embankment/sub-grade foundation and replacement with suitable material shall be measured in cu.m.

Scarifying existing granular/bituminous road surface shall be measured in square metres.

Dismantling and removal of existing cement concrete pavement shall be measured vide Clause 202.6.

Filter medium and backfill material behind abutments, wing walls and other retaining structures shall be measured as finished work in position in cu.m.

305.9 Rates

305.9.1 The Contract unit rates for the items of embankment and sub-grade construction shall be payment in full for carrying out the required operations including full compensation for :

i) Cost of arrangement of land as a source of supply of material of required quantity for construction unless provided otherwise in the Contract;

ii) Setting out;

iii) Compacting ground supporting embankment/sub-grade except where removal and replacement of suitable material or loosening and recompacting is involved;

iv) Scarifying or cutting continuous horizontal benches 300 mm wide on side slopes of existing embankment and sub-grade as applicable;

v) Cost of watering or drying of material in borrow areas and/or embankment and sub-grade during construction as required;

vi) Spreading in layers, bringing to appropriate moisture and compacting to Specification requirements;

vii) Shaping and dressing top and slopes of the embankment and sub-grade including rounding of corners;

viii) Restricted working at sites of structures;

ix) Working on narrow width of embankment and sub-grade;

x) Excavation in all soils from borrow pits/designated borrow areas including clearing and grubbing and transporting the material to embankment and sub-grade site with all lifts and leads unless otherwise provided for in the Contract;

xi) All labour, materials, tools, equipment and incidentals necessary to complete the work to the Specifications;

xii) Dewatering; and

xiii) Keeping the embankment/completed formation free of water as per Clause 311.

305.9.2 Clause 301.9.5 shall apply as regards Contract unit rates for items of stripping and storing top soil and of reapplication of topsoil.

305.9.3 Clause 301.9.2 shall apply as regards Contract unit rate for the item of loosening and recompacting the embankment/sub-grade foundation.

305.9.4 Clause 309.1.1 and 305.8 shall apply as regards Contract rates for items of removal of unsuitable material and replacement with suitable material respectively.

305.9.5 The Contract unit rate for scarifying existing granular/bituminous road surface shall be payment in full for carrying out the required operations including full compensation for all labour, materials, tools, equipment and incidentals, necessary to complete the work. This will also comprise of handling, giving credit towards salvage value and disposal of the dismantled materials with all leads and lifts or as otherwise specified.

305.9.6 Clause 202.7 shall apply as regards Contract unit rate for dismantling and removal of existing cement concrete pavement.

305.9.7 The Contract unit rate for providing and laying filter material behind abutments shall be payment in full for carrying out the required operations including all materials, labour, tools, equipment and incidentals to complete the work to Specifications.

305.9.8 Clause 305.4.6 shall apply as regards Contract unit rate for construction of embankment under water.

305.9.9 Clause 305.4.7 shall apply as regards Contract unit rate for construction of high embankment. It shall include cost of instrumentation, its monitoring and settlement period, where specified in the Contract or directed by the Engineer.

306 SOIL EROSION AND SEDIMENTATION CONTROL

306.1 Description

This work shall consist of measures as shown on plans or as directed by the Engineer to control soil erosion, sedimentation and water pollution, through use of berms, dikes, sediment basins, fibre mats, mulches, grasses, slope drains, and other devices.

306.2 Materials

All materials shall meet commercial grade standards and shall be approved by the Engineer before being used in the work.

306.3 Construction Operations

Prior to the start of the relevant construction, the Contractor shall submit to the Engineer for approval his schedules for carrying out temporary and permanent erosion/sedimentation

control works as are applicable for the items of clearing and grubbing, roadway and drainage excavation, embankment/sub-grade construction, bridges and other structures across water courses, pavement courses and shoulder. He shall also submit for approval his proposed method of erosion/sedimentation control on service road and borrow pits and his plan for disposal of waste materials. Work shall not be started until the erosion/ sedimentation control schedules and methods of operations for the applicable construction have been approved by the Engineer.

The surface area of erodible earth material exposed by clearing and grubbing, excavation, borrow and fill operations shall be limited to the extent practicable. The Contractor may be directed to provide immediate permanent or temporary erosion and sedimentation control measures to prevent soil erosion and sedimentation that will adversely affect construction operations, damage adjacent properties, or cause contamination of nearby streams or other water courses, lakes, reservoirs etc. Such work may involve the construction of temporary berms, dikes, sediment basins, slope drains and use of temporary mulches, fabrics, mats seeding, or other control devices or methods as necessary to control erosion and sedimentation. Cut and fill slopes shall be seeded and turfed as required on the plans.

The Contractor shall be required to incorporate all permanent erosion and sedimentation control features into the project at the earliest practicable time as outlined in his accepted schedule to minimize the need for temporary erosion and sedimentation control measures.

Temporary erosion/sedimentation and pollution control measures will be used to control the phenomenon of erosion, sedimentation and pollution that may develop during normal construction practices, but may neither be foreseen during design stage nor associated with permanent control features on the Project.

Where erosion or sedimentation is likely to be a problem, clearing and grubbing operations should be so scheduled and performed that grading operations and permanent erosion or sedimentation control features can follow immediately thereafter if the project conditions permit; otherwise temporary erosion or sedimentation control measures may be required between successive construction stages. Under no conditions shall a large surface area of erodible earth material be exposed at one time by clearing and grubbing or excavation without prior approval of the Engineer.

The Engineer may limit the area of excavation, borrow and embankment operations in progress, commensurate with the Contractor’s capability and progress in keeping the finish grading, mulching, seeding and other such permanent erosion, sedimentation and pollution control measures, in accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion/sedimentation control measures shall be taken immediately to the extent feasible and justified.

In the event temporary erosion, sedimentation and pollution control measures become necessary due to the Contractor's negligence, carelessness or failure to install permanent controls as a part of the work as scheduled or ordered by the Engineer, these shall be carried out at the Contractor's own cost. Temporary erosion, sedimentation and pollution control work required, which is not attributed to the Contractor's negligence, carelessness or failure to install permanent controls, will be performed as ordered by the Engineer.

Temporary erosion, sedimentation and pollution control may include construction work outside the right-of-way where such work is necessary as a result of road construction such as borrow pit operations, service roads and equipment storage sites.

The temporary erosion, sedimentation and pollution control features installed by the Contractor shall be acceptably maintained by him till these are needed, unless otherwise agreed by the Engineer.

306.4 Measurement for Payment

The soil erosion, sedimentation and pollution control works will be measured in terms of units specified in the Bill of Quantities for the respective items.

306.5 Rates

The Contract unit rate for different items of soil erosion, sedimentation and pollution control works shall be payment in full for carrying out all required operations including full compensation for all labour, tools, equipment and incidentals to complete the works to the Specifications.

307 TURFING WITH SODS

307.1 Scope

This work shall consist of furnishing and laying of the live sod of perennial turf forming grass on embankment slopes, verges (earthen shoulders) or other locations shown on the drawings or as directed by the Engineer. Unless otherwise specified, the work shall be taken up as soon as possible following construction of the embankment, provided the season is favourable for establishment of the sod.

307.2 Materials

The sod shall consist of dense, well-rooted growth of permanent and desirable grasses, indigenous to the locality where it is to be used, and shall be practically free from weeds or other undesirable matter. At the time the sod is cut, the grass on the sod shall have a length of approximately 50 mm and the sod shall have been freed of debris.

Thickness of the sod shall be as uniform as possible, with some 50-80 mm or so of soil covering the grass roots depending on the nature of the sod, so that practically all the dense root system of the grasses is retained in the sod strip. The sods shall be cut in rectangular strips of uniform width, not less than about 250 mm x 300 mm in size but not so large that it is inconvenient to handle and transport these without damage. During wet weather, the sod shall be allowed to dry sufficiently to prevent rearing during handling and during dry weather shall be watered before lifting to ensure its vitality and prevent the dropping of the soil in handling.

307.3 Construction Operations

307.3.1 Preparation of the earth bed : The area to be sodded shall have been previously constructed to the required slope and cross-section. Soil on the area shall be loosened, freed of all stones larger than 50 mm size, sticks, stumps and any undesirable foreign matter, and brought to a reasonably fine granular texture to a depth of not less than 25 mm for receiving the sod.

Where required, topsoil shall be spread over the slopes. Prior to placing the topsoil, the slopes shall be scarified to a depth which, after settlement, will provide the required nominal depth shown on the plans. Spreading shall not be done when the ground is excessively wet.

Following soil preparation and top soiling, where required, fertilizer and ground limestone when specified shall be spread uniformly at the rate indicated on the plans. After spreading, the materials are incorporated in the soil by discing or other means to the depths shown on the plans.

307.3.2 Placing the sods : The prepared sod bed shall be moistened to the loosened depth, if not already sufficiently moist, and the sod shall be placed thereon within approximately 24 hours after the same had been cut. Each sod strip shall be laid edge to edge and such that the joints caused by abutting ends are staggered. Every strip, after it is snugly placed against the strips already in position, shall be lightly tamped with suitable wooden or metal tampers so as to eliminate air pockets and to press it into the underlying soil.

On side slopes steeper than 2 (horizontal) to 1 (vertical), the laying of sods shall be started from bottom upwards. At points where water may flow over a sodded area, the upper edges of the sod strips shall be turned into the soil below the adjacent area and a layer of earth placed over this followed by its thorough compaction.

307.3.3 Staking the sods : Where the side slope is 2 (horizontal) to 1 (vertical) or steeper and the distance along the slope is more than 2 m, the sods shall be staked with pegs or nails spaced approximately 500 to 1000 mm along the longitudinal axis of the sods strips. Stakes shall be driven approximately plumb through the sods to be almost flush with them.

307.3.4 Top dressing : After the sods have been laid in position, the surface shall be cleaned of loose sod, excess soil and other foreign material. Thereafter, a thin layer of topsoil shall be scattered over the surface of top dressing and the area thoroughly moistened by sprinkling with water.

307.3.5 Watering and maintenance : The sods shall be watered by the Contractor for a period of at least four weeks after laying. Watering shall be so done as to avoid erosion and prevent damage to sodded areas by wheels of water tanks.

The Contractor shall erect necessary warning signs and barriers, repair or replace sodded areas failing to show uniform growth of grass or damaged by his operations and shall otherwise maintain the sod at his cost until final acceptance.

307.4 Measurements for Payment

Turfing with sods shall be measured as finished work in square metres.

307.5 Rate

The Contract unit rate for turfing with sods shall mean paying in full for carrying out all the required operations explained above including compensation for

i) furnishing all the materials to be incorporated in the Works with all leads and lifts; and

ii) all labour, tools, equipment and incidentals to complete the work in accordance with these Specifications.

The Contract unit rate for application of topsoil shall be as per Clause 301.9.5.

308 SEEDING AND MULCHING

308.1 Scope

This shall consist of preparing slopes, placing topsoil, furnishing all seeds, commercial or organic fertilizers and mulching materials, providing jute netting and placing and incorporating the same on embankment slopes or other locations designated by the Engineer or shown in the Contract documents.

308.2 Materials

A. **Seeds:** The seeds shall be of approved quality and type suitable for the soil on which these are to be applied, and shall give acceptable purity and germination to requirements set down by the Engineer.

Fertilizers shall consist of standard commercial materials and conform to the grade specified. Organic manure shall be fully putrified organic matter such as cow dung.

Mulching materials shall consist of straw, hay, wood shavings, or sawdust and shall be delivered dry. They shall be reasonably free of weed seed and such foreign materials as may detract from their effectiveness as a mulch or be injurious to the plant growth.

B. **Topsoil :** Topsoil shall not be obtained from an area known to have noxious weeds growing in it. If treated with herbicide or sterilents, it shall be got tested by appropriate agricultural authority to determine the residual in the soil. Topsoil shall not contain less than 2 percent and more than 12 percent organic matter.

C. **Bituminous Emulsion :** A suitable grade of bituminous cutback or emulsion used as a tie down for mulch shall be as described in the Contract document or as desired by the Engineer. Emulsified bitumen shall not contain any solvent or diluting agent toxic to plant life.

D. **Netting :** Jute netting shall be undyed jute yarn woven into a uniform open weave with approximate 2.5 cm square openings.

Geonetting shall be made of uniformly extruded rectangular mesh having mesh opening of 2 cm x 2 cm. The colour may be black or green. It shall weigh not less than 3.8 kg per 1000 sq.m.

308.3 Seeding Operations

308.3.1 Seed-bed preparation : The area to be seeded shall be brought to the required slope and cross-section by filling, reshaping eroded areas and refinishing slopes, medians etc. Topsoil shall be evenly spread over the specified areas to the depth shown on the plans, unless otherwise approved by the Engineer. The seed-bed preparation shall consist of eliminating all live plants by suitable means using agricultural implements. All stones 150 mm in smallest dimension and larger shall be removed. The soil shall be excavated on the contour to a depth of 100 mm. All clods larger than 25 mm in diameter shall be crushed and packed. Where necessary, water shall then be applied. All topsoil shall be compacted unless otherwise specified or approved by the Engineer. Compaction shall be by slope compactor, cleated tractor or similar equipment approved by the Engineer. Equipment shall be so designed and constructed as to produce a uniform rough textured surface ready for seeding and mulching and which will bond the topsoil to the underlying material. The entire area shall be covered by a minimum of 4 passes or 2 round trips of the roller or approved equipment.

308.3.2 Fertilizer application: Fertilizer to the required quantities shall be spread and thoroughly incorporated into the soil surface as a part of the seed-bed preparation.

308.3.3 Planting of seeds : All seeds shall be planted uniformly at the approved rate. Immediately after sowing, the area shall be raked, dragged or otherwise treated so as to cover the seeds to a depth of 6 mm.

The operation of seed sowing shall not be performed when the ground is muddy or when the soil or weather conditions would otherwise prevent proper soil preparation and subsequent operations.

308.3.4 Soil moisture and watering requirements : Soil moisture shall exist throughout the zone from 25 mm to at least 125 mm below the surface at the time of planting.

Watering of the seeded areas shall be carried out as determined by the Engineer.

308.4 Mulching, Applying Bituminous Emulsion and Jute Netting/ Geonetting

Within 24 hours of seeding, mulching material mixed with organic manure shall be placed so as to form a continuous, unbroken cover of approximate uniform thickness of 25 mm using an acceptable mechanical blower. Mulching material shall be held in place and made resistant to being blown away by suitable means approved by the Engineer. When called for in the Contract documents, mulch material shall be anchored in place with bituminous emulsion applied at the rate of 2300 litres per hectare. Any mulch disturbed or displaced following application shall be removed, reseeded and remulched as specified. Jute netting/geonetting shall be unrolled and placed parallel to the flow of water immediately following the bringing, to finished grade, the area specified on the plans or the placing of seed and fertilizer. Where more than one strip is required to cover the given areas, they shall overlap a minimum of 100 mm. Jute netting/Geonetting shall be held in place by approved wire staples, pins, spikes or wooden stakes driven vertically into the soil.

308.5 Maintenance

The Contractor shall maintain all seeded and mulched areas until final acceptance. Maintenance shall include protection of traffic by approved warning signs or barricades and repairing any areas damaged following the seeding and mulching operations. If mulched areas become damaged, the area shall be reshaped and then seeded and mulched again as originally specified.

308.6 Measurements of Payment

Seeding and mulching shall be measured as finished work in square metres.

308.7 Rate

The Contract unit rate for seeding and mulching shall be payment in full for carrying out all the required operations including full compensation for all materials, labour, tools and incidentals.

309 SURFACE/SUB-SURFACE DRAINS

309.1 Scope

The work shall consist of constructing surface and/or sub-surface drains in accordance with the requirements of these Specifications and to the lines, grades, dimensions and other particulars shown on the drawings or as directed by the Engineer. Schedule of work shall be so arranged that the drains are completed in proper sequence with road works to ensure that no excavation of the completed road works is necessary subsequently or any damage is caused to these works due to lack of drainage.

309.2 Surface Drains

Surface drains shall be excavated to the specified lines, grades, levels and dimensions to the requirements of Clause 301. The excavated material shall be removed from the area adjoining the drains and if found suitable, utilized in embankment/sub-grade construction. All unsuitable material shall be disposed of as directed.

The excavated bed and sides of the drains shall be dressed to bring these in close conformity with the specified dimensions, levels and slopes.

Where so indicated, drains shall be lined or turfed with suitable materials in accordance with details shown on the drawings.

All works on drain construction shall be planned and executed in proper sequence with other works as approved by the Engineer, with a view to ensuring adequate drainage for the area and minimizing erosion/sedimentation.

309.3 Sub-Surface Drains

309.3.1 Scope : Sub-surface drains shall be of close-jointed perforated pipes, open-jointed unperforated pipes, surrounded by granular material laid in a trench or aggregate

drains to drain the pavement courses. Sub-surface drains designed using Geosynthetics and approved by the Engineer can also be used.

309.3.2 Materials

A. **Pipe :** Perforated pipes for the drains may be metal/asbestos cement/cement concrete/PVC, and unperforated pipes of vitrified clay/ cement concrete/asbestos cement. The type, size and grade of the pipe to be used shall be as specified in the Contract. In no case, however, shall the internal diameter of the pipe be less than 100 mm. Holes for perforated pipes shall be on one half of the circumference only and conform to the spacing indicated on the drawings. Size of the holes shall not ordinarily be greater than half of D_{85} size of the material surrounding the pipe, subject to being minimum 3 mm and maximum 6 mm. D_{85} stands for the size of the sieve that allows 85 percent of the material to pass through it.

B. **Backfill material :** Backfill material shall consist of sound, tough, hard, durable particles of free draining sand-gravel material or crushed stone and shall be free of organic material, clay balls or other deleterious matter. Unless the Contract specified any particular gradings for the backfill material or requires these to be designed on inverted filter criteria for filtration and permeability to the approval of the Engineer, the backfill material shall be provided on the following lines:

i) Where the soil met with in the trench is of fine grained type (e.g., silt, clay or a mixture thereof), the backfill material shall conform to Class I grading set out in-Table 300-4;

ii) Where the soil met with in the trench is of coarse silt to medium sand or sandy type, the backfill material shall correspond to Class II grading of Table 300-4; and

iii) Where soil met with in the trench is gravelly sand, the backfill material shall correspond to Class III grading of Table 300-4.

Thickness of backfill material around the pipe shall be as shown on the drawings subject to being at least 150 mm alround in all cases.

Geosynthetics for use with subsurface drain shall conform to the requirements as per Section 700.

309.3.3 Trench excavation : Trench for sub-surface drain shall be excavated to the specified lines, grades and dimensions shown in the drawings provided that width of

trench at pipe level shall not be less than 450 mm. The excavation shall begin at the outlet end of the drain and proceed towards the upper end. Where unsuitable material is met with at the trench bed, the same shall be removed to such depth as directed by the Engineer and backfilled with approved material which shall be thoroughly compacted to the specified degree.

309.3.4 Laying of pipe and backfilling : Laying of pipe in the trench shall be started at the outlet end and proceed towards the upper end, true to the lines and grades specified. Unless otherwise provided, longitudinal gradient of the pipe shall not be less than 1 in 100.

Table 300-4 Grading Requirements for Filter Material

Sieve Designation	Per cent passing by weight		
	Class I	Class II	Class III
53 mm	-	-	100
45 mm	-	-	97-100
26.5 mm	-	100	-
22.4 mm	-	95-100	58-100
11.2 mm	100	48-100	20-60
5.6 mm	92-100	28-54	4-32
2.8 mm	83-100	20-35	0-10
1.4 mm	59-96	-	0-5
710 micron	35-80	6-18	-
355 micron	14-40	2-9	-
180 micron	3-15	-	-
90 micron	0-5	0-4	0-3

Before placing the pipe, backfill material of the required grading(s) shall be laid for full width of the trench bed and compacted to a minimum thickness of 150 mm or as shown on the drawings. The pipe shall then be embedded firmly on the bed.

Perforated pipes, unless otherwise specified, shall be placed with their perforations down to minimize clogging. The pipe sections shall be joined securely with appropriate coupling fittings or bands.

Non-perforated pipes shall be laid with joints as close as possible with the open joints wrapped with suitable pervious material (like double layer of Hessian, suitable Geosynthetics or some other material of not less than 150 mm width) to permit entry of water but prevent fines entering the pipes. In the case of non-perforated pipes with bell end, the bell shall face upgrade.

Upgrade end sections of the pipe installation shall be tightly closed by means of concrete plugs or plugs fabricated from the same material as the pipe and securely held in place to prevent entry of soil materials.

After the pipe installation has been completed and approved, backfill material of the required grading (s) (see Clause 309.3.2B) shall be placed over the pipe to the required level in horizontal layers not exceeding 150 mm in thickness and thoroughly compacted. The minimum thickness of material above the top of the pipe shall be 300 mm.

Unless otherwise provided, sub-surface drains not located below the road pavement shall be sealed at the top by means of 150 mm thick layer of compacted clay so as to prevent percolation of surface water.

309.3.5. Use of geosynthetic in laying of pipe and backfilling : After excavating the trench for subsurface drain, the filter fabric shall be placed, the pipe installed and the trench backfilled with permeable material according to dimensions and details shown on the plans. Surfaces to receive filter fabric prior to placing shall be free of loose or extraneous material and sharp objects that may damage the filter fabric during installation. Adjacent rolls of the fabric shall be overlapped a minimum of 450 mm. The preceding roll shall overlap the following roll in the direction the material is being spread.

Damage to the fabric resulting from Contractor's vehicles, equipment or operations shall be replaced or repaired by the Contractor at his Cost.

309.3.6 Drain outlet : The outlet for a sub-drain shall not be under water or plugged with debris but should be a free outlet discharging into a stream, culvert or open ditch. The bottom of the pipe shall be kept above high water in the ditch and the end protected with a grate or screen. For a length of 500 mm from the outlet end, the trench for pipe shall not be provided with granular material but backfilled with excavated soil and thoroughly compacted so as to stop water directly percolating from the backfill material around the pipe. The pipe in this section shall not have any perforations.

309.3.7. Aggregate drains : Aggregate drains shall be placed within the verge/ shoulders after completion of the pavement. Depth, thickness and spacing of the aggregate drains shall be as shown on the plan.

Trenches for aggregate drains shall be excavated to a minimum width of 300 mm and to the depth shown on the plans or ordered by the Engineer. The bottom of the trench shall be sloped to drain and shall be free from loose particles of soil. The trench shall be excavated so as to expose clearly the granular pavement courses to be drained.

Aggregate for the drains shall be durable gravel, stone or slag and shall be free from vegetable matter and other deleterious substances. The grading requirements are given

in Table 300-5. Type B grading may be used only where the drain is designed to intercept surface water flowing to the pipe and is likely to get slowly blocked. Type A grading allows a much wider range.

Table 300-5 Grading Requirements for Aggregate Drains

Sieve Designation	Per cent passing by weight	
	Type A	Type B
63 mm	-	100
37.5 mm	100	85– 100
19 mm	-	0 – 20
9.5 mm	45 – 100	0 – 5
3.35 mm	25 – 80	-
600 micron	8 – 45	-
150 micron	0 – 10	-
75 micron	0 – 5	-

309.4 Measurements for Payment

Measurement for surface and sub-surface drains shall be per running metre length of the drain.

309.5 Rates

The Contract unit rates for surface and sub-surface drains shall be payment in full for all items such as excavation, dressing the sides and bottom; providing lining, turfing, pitching, masonry, concrete and plastering; providing, laying and jointing pipes; providing, laying and compacting backfill and bed of granular material; providing, fixing and painting of cover etc. including full compensation for all materials, labour, tools, equipment and other incidentals to complete the work as shown on drawings with all leads and lifts including for removal of unsuitable material. Provision of inlets, gratings, sumps, outlet pipes, bedding, disbursers etc. wherever required shall be incidental to construction of drain.

310 PREPARATION AND SURFACE TREATMENT OF FORMATION

Preparation and surface treatment of the formation, that is top of the subgrade, shall be carried out only after completion of any specified sub-grade drainage and unless otherwise agreed by the Engineer, immediately prior to laying the sub-base or the road base where no sub-base is required. The sequence of operations shall be as follows:

a) All surfaces below carriageway, laybyes, footways and hard shoulders shall, after reinstatement of any soft areas to the required Specifications be well cleaned and freed of mud and slurry.

b) The surface shall be compacted by 4 passes of a smooth wheeled roller of 80 to 100 kn weight after spraying requisite amount of water, if required, before the commencement of rolling.

c) The formation shall, wherever necessary be regulated and trimmed to the requirements of Clause 305.3.9 with motor grader.

d) The trimmed formation shall be rolled by one pass of smooth wheeled roller of 80 to 100 kn weight after spraying requisite amount of water, if required, before the commencement of rolling.

Where the completed formation is not immediately covered with sub-base or road base material, its moisture content shall be maintained to prevent cracking in the formation by suitable measures as approved by the Engineer. The entire work of surface treatment of formation shall be deemed as incidental to the work of sub-base/base course to be provided for the same.

311 WORKS TO BE KEPT FREE OF WATER

311.1 The Contractor shall arrange for the rapid dispersal of water collected/ accumulated on the earthwork or completed formation during construction or on the existing roadway or which enters the earthwork or any other item of work from any source, and where practicable, the water shall be discharged into the permanent outfall of the drainage system. The arrangements shall be made in respect of all earthwork including excavation for pipe trenches, foundations or cuttings.

311.2 The Contractor shall provide, where necessary, temporary water courses, ditches, drains, pumping or other means for maintaining the earthwork free from water. Such provisions shall include carrying out the work of forming the cut sections and embankments in such manner that their surfaces have at all times a sufficient minimum crossfall and, where practicable, a sufficient longitudinal gradient to enable them to shed water and prevent ponding.

The works involved in keeping the earthwork or any other item of works free of water shall be deemed as incidental to the respective item of work and as such no separate payment shall be made for the same.

312 WATER COURSES AT CULVERTS

312.1 Excavation carried out in the diversion, enlargement, deepening or straightening water courses at culverts, where necessary, shall include the operations such as clearing, grubbing, removal of vegetation, trimming of slopes, grading of beds, disposal of excavated materials, pumping, timbering etc. necessary for dealing with the flow of water.

312.2 The beds and sloping sides of water courses shall, where shown on the drawings, be protected against the action of water by rubble paving to form a flat or curved surface as indicated. The protection shall consist of large smooth faced stones or of blocks of precast concrete. Stones for rubble paving shall be roughly dressed square. No stone shall be less than 225 mm in depth nor less than 0.02 cu.m in volume and no rounded boulders shall be used. After completion of construction of culverts, temporary diversion of water course, if any, shall be closed and water course restored for flow through the culvert as per the direction of the Engineer.

312.3 Measurements for Payment

The work for water courses at culverts as stated above shall be measured in terms of units specified in the Bill of Quantities for respective items. The temporary diversion of channel to facilitate construction of culverts, its closure and restoration to original water course shall be considered incidental to the work of construction of culvers and no extra payment shall be made for the same.

312.4 Rates

The Contract unit rates for different items of water courses at culverts shall be payment in full for carrying out all required operations including full compensation for all cost of materials, labour, tools, equipment and other incidentals to complete the work to the Specifications.

313 CONSTRUCTION OF ROCKFILL EMBANKMENT

313.1 Scope

In normal circumstances, the embankment should not be constructed with rockfill material. However, where specifically permitted by the Engineer because of imperative economic or technical reasons, construction of rockfill embankments shall be in accordance with the lines, grades and cross-sections as shown in drawings or as directed by the Engineer.

Rockfill shall not be used at least for a depth of 500 mm below the formation level. There should be a minimum of 500 mm thick earthen cushion over the rockfill.

313.2 Materials

The size of rock pieces used in rockfill embankments shall be such that they can be deposited in layers so as to suit the conditions evaluated in the field compaction trials or as directed by the Engineer. The rockfill shall consist of hard, durable and inert material, preferably maximum size not exceeding 300 mm and percent finer than 125 mm not exceeding 10 percent.

Argillaceous rocks (clay, shales etc,), unburnt colliery stock and chalk shall not be used in rockfill.

The rock fragments and blinding material required for filling the voids shall also satisfy the above requirements.

313.3 Spreading and Compaction

The material shall be tipped, spread and leveled in layers extending to the full width of embankment by a suitable dozer. Fragments of rock shall then be spread on the top of layer to the required extent and layer compacted by minimum of 5 passes of vibratory roller having static weight 8-10 tonnes. The compacted thickness of each layer shall not exceed 500 mm. After compaction of each layer, the surface voids shall be filled with broken fragments. Next layer, where required, shall be placed in the same manner, above the earlier compacted layer.

The top layer of rockfill, on which normal earth fill will rest shall be thoroughly blinded with suitable granular material to seal its surface.

313.4 Measurements for Payment

Measurement shall be made by taking cross-sections at intervals in the original position before the work starts and after its completion and computing the volume in cu.m by the method of average end areas.

313.5 Rate

The Contract unit rate shall be paid in full for carrying out all the above operations including cost of rockfill, broken fragments and blinding material and shall provide full compensation for all items as per clause 305.8.

314 Ground improvement for problematic conditions at embankment foundation like having sub-soil strata with low shear strength and high compressibility

314.1 **Scope :** The scope for improving the ground of problematic sub-soil conditions comprises of several alternatives and one out of the following alternatives may be chosen based on the sub-soil conditions :

i) Excavation and replacement of weak sub-soil layer with well draining coarse sand (natural or crushed) conforming to Class I grading given in Table 300-3, compacted to a relative density of 75 to 80 percent shall be provided.

ii) Stage construction of embankment and controlled rate of filling (build the embankment for a height the sub-soil strength permits, wait for settlements to happen, build next lift of the embankment and so on).

iii) Using geosynthetic drains (Prefabricated Vertical Drain (PVD)] with surcharge involving design and installation of PVD to achieve 90% consolidation of sub-soil by a prescribed time (6 months, 12 months, etc.)

iv) Rammed stone columns.

v) Stone columns formed by vibroflot technique.

314.2 Prefabricated Vertical Drain (PVD) with surcharge : The design and construction of this drain shall generally comply with the requirements of IS:15284 (Part 2), including all latest amendments and specifically with the requirements of this Particular Specification. In the case of conflict between the requirements of IS:15284 and this Particular Specification the requirements of this Particular Specification shall prevail.

314.2.1 Materials :

i) **Geosynthetic Drain :** Geosynthetic strip or band drain manufactured conforming to ISO 9001 certification shall consist of a corrugated or studded or 3-d mesh consisting of an inner core of thick polyester fused at intersection, wrapped in a non-woven geotextile. Band drain shall be 100 mm wide and 5 mm thick. The core shall serve as the drainage medium conveying the core water from the soft subsoil to the drainage layer at the top. The core shall be of three-dimensional mesh, made of polyester or equivalent. The filter should be Non-woven needle punched adhesive-bonded fabric. The filter and the core shall be ultrasonically welded together at edges to produce a fully integrated product. The drain shall meet the following properties:

	UNIT	MEAN VALUE	TEST METHOD
COMPOSITE			
Weight	G/m	75 + 10%	ASTM D-5261
Width	Mm	100	
Thickness	Mm	5.0	ASTM D-5199
Tensile Strength	KN	2.2	ASTM D-4595
Elongation at 2.0 kn	%	25	ASTM D-4595
Strength at 10% elongation	KN	1.3	ASTM D-4595

	UNIT	MEAN VALUE	TEST METHOD
Discharge capacity q			
Index text using deformable foam layers	M^3/s	60×10^{-6} (300kPa) 40×10^{-4} (500 kPa)	ASTM D-4716
Straight – embedded in bentonite	M^3/s	90×10^{-6}	ASTM D-4716
Buckled – embedded in bentonite	M^3/s	80×10^{-6}	ASTM D-4716
Filter Fabric			
Puncture Strength	N	150	ASTM D-4595
Tear strength	N	200	ASTM D-4595
Grab tensile strength	N	550	ASTM D-4595
A.o.s. (095)	Mm	100	ASTM D-4751
Permeability (kv)	Cm/s	200 x 100	ASTM D-4491

The drains shall be installed to depths and at spacing as per the design. The contractor shall submit to the Engineer the complete design considering 90 percent consolidation to be achieved by a prescribed time (6 months, 12 months, etc) and scheme for installation of vertical band drains alongwith the particulars of brand of drain being used with its properties, the equipment and the methodology being used for installation of the drains.

ii) Granular Sand Blanket : After installation of the vertical band drains in the sub-soil, a blanket of well draining coarse sand (natural or crushed) conforming to Class I grading given in Table 300-3 of suitable thickness compacted to a relative density of 75 to 80 percent shall be provided. This blanket shall be exposed to atmosphere at its periphery for pore water pressure dissipation.

iii) Geotextile Fabric for separation and drainage : The finished sand blanket shall be covered with a geotextile layer on top and bottom before applying pre-load/ construction of embankment. The geotextile used for this purpose shall be a non-wowen, manufactured conforming to ISO 9001 certification and made of polyprophylene using endless continuous filament of polypropylene and thermally bonded by heat set. The geotextile and the threads used shall be resistant to chemical attack, mildew and rot. The requirements of polypropylene, needle

punched, non woven geotextile fabric used for this purpose are given below

Properties	Units	Fabric
PHYSICAL		
Grab Tensile Strength	KN	0.900
Grab Tensile Elongation	%	50
Mullen Burst	KPA	2750
Puncture	KN	0.575
Trapezoid Tear	KN	0.355
UV Resistance	%@ hr	70/500
HYDRAULIC		
Apparent Opening Size (AOS)	Mm	0.150
Permittivity	Sec	1.5
Flow Rate	$1/min/m^2$	3225
Life Period	Years	120
MINIMUM AVERAGE ROLL VALUES		

314.2.2 Construction and installation requirements:

i) **Shipment and Storage :** The Geosynthetic Band Drain shall be dry and wrapped such that it is protected from the exposure to ultraviolet light during shipping and storage. At no time shall the band drain be exposed to ultraviolet light for a period exceeding fourteen days. If stored outdoor, they shall be elevated and protected with a waterproof cover. The Geo-synthetic Band Drain shall be labeled as per ASTM D 4873, “Guide for identification, storage, and handling of geotextile.

ii) **Drain installation :** Band Drains in roll shall be installed using an installation rig/sticher mounted on a base machine (Hydraulic or Mechanical). The end of the drain shall be attached to a hollow rectangular mandrel or shoe, which will be driven into the soft clay by appropriate mechanism, such as lance. On reaching the refusal strata (stiff soil), the mandrel with the drain shall be left behind and the lance withdrawn. The top of the drain above the ground level shall be cut off at design level (150 mm into the drainage blanket). The rig/ sticher moves on to the next location.

iii) After installation of vertical band drains, a blanket of granular coarse sand as mentioned above shall be spread over the entire area and covered with geotextile layer on top and bottom as directed by the Engineer.

iv) **Installation of geotextile fabric for separation and drainage :**

a) **Shipment and Storage :** The geotextile shall be kept dry and wrapped such that it is protected from the exposure to ultraviolet light during shipping and storage. At no time shall the paving fabric be exposed to ultraviolet light for a period exceeding fourteen days. Geotextile rolls shall be stored in a manner, which protects them from elements. If stored outdoor, they shall be elevated and protected with a waterproof cover. The geotextile shall be labeled as per ASTM D 4873, "Guide for identification, storage and handling of geotextiles".

b) **Fabric Placement :** The geotextile shall be laid smooth without wrinkles or folds on the sand blanket in the direction of construction traffic. Adjacent geotextile rolls shall be overlapped, sewn or jointed, (Preferably sewn or joined). On curves the geotextile may be folded or cut & overlap to conform to the curves. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock. Prior to covering, the geotextile shall be inspected by the Engineer to ensure that the geotextile has not been damaged (i.e. holes, tears, rips) during installation. Damaged geotextiles, as identified by the Engineer, shall not be allowed. The surcharge shall be placed such that atleast the minimum specified lift thickness shall be between the geotextile and the equipment tyres or tracks at all times. Turning of vehicles shall not be permitted on the first lift above the geotextile.

c) **Seaming :** A sewn seam is to be used for the seaming of the geotextile. The thread used shall consist of high strength polypropylene or polyester. Nylon thread shall not be used. The thread shall also be resistant to ultraviolet radiation. The thread shall be of contrasting color to that of the geotextile itself. For seams which are sewn in the filed, the contractor shall provide at least a 2 metre length sewn seam for sampling by the Engineer before the geo-textile is installed. For seams which are sewn in the factory, the Engineer shall obtain samples of the factory seams at random from any roll of geotextile which is used on the project. For seams that are field sewn, the seams sewn for sampling shall be sewn using the same equipment and procedures as will be used for the production seams. If seams area sewn in both the machine and cross machine direction, samples of seams from both directions shall be provided. The seam assembly description

shall be submitted by the Contractor along with the sample of the seam. The description shall include the seam type, stitch type, sewing thread and stitch density.

v) **Addition of Surcharge :** Addition of surcharge load by approved embankment material shall be placed over the geotextile layer upto a height as per the design requirement. The addition of surcharge shall be placed with adequate side slope to avoid any slope failure. The addition of surcharge needs to be kept in place for a period as per the design to achieve desired degree of consolidation. After ascertaining that the desired degree of consolidation is achieved, the addition of surcharge which is not forming part of permanent work/ embankment shall be removed to the required level as per drawings. Removal of additional surcharge material shall be done without damaging the road embankment. After removal of additional surcharge, the damaged embankment top, if any, shall be made good as instructed by the Engineer-in-charge. The addition and removal of surcharge is incidental to the work except for payment of additional surcharge quantity forming part of permanent embankment. The quantity for payment will be determined based on the settlements readings observed through instrumentation.

vi) **Instrumentation and Monitoring the behaviour of sub-soil/ embankment :** Monitoring the behavior of the sub-soil/ embankment construction shall form part of the scope. The design is based on the gain in the shear strength of the subsoil due to consolidation process. It is therefore necessary to monitor the following critical parameters :

a) **Monitoring the build up and dissipation of Pore Pressure :** Casagrande open standpipe type piezometers shall be used for the measurement of changes in pore pressure. The specifications for the casagrande piezometer are as follows.

The piezometer shall be 38 mm in dia and 300 mm in length;

The air entry value shall be of the order of 0.3 kg/cm^2. The standpipe shall be more than 16 mm in diametre;

The piezometer shall be installed in 150 mm borehole, at specified depths. Sand cover around the piezometer tip and bentonite seal above shall be provided; and

Suitable electronic sensor shall be used to record the water level

Piezometers including dummy piezometers shall be installed at locations specified by the Engineer.

b) **Rate and Magnitude of Vertical Settlements of the Subsoil under the surcharge load :** Settlements shall be measured by installing platform type settlement gauges, which consist of the following :

Wooden base plate 1000 mm square and 50 mm thick;

GI pipe of 25 mm ö fitted to the base plate with a suitable sleeve arrangement and nuts and bolts;

Outer loose fitting sleeve, to prevent soil form coming into contact with the inner pipe;

The pipe and the sleeve consist of 1.5m long sections, which can be screwed on at the top, so that as the surcharge is built up, the top of the pipe is well clear of the fill;

Settlement gauges shall be installed at the ground level, before the starting of the fill construction. These shall be installed locations specified by the Engineer. The readings of settlement gauges also form the basis to estimate the quantity of surcharge forming part of permanent work. The number of settlement gauges is also to be decided by the Engineer keeping in view this aspect.

c) **Measurement of Shear Strength : T**he shear strength parameters of the subsoil [unconfined compressive strength (UCS)] shall be measured at locations specified by the Engineer at the end of each stage of surcharge loading in order to compare the actual details with the design assumptions. For the recovery of undisturbed samples from the subsoil for determining UCS, before start of construction of surcharge, 100 mm dia casing pipe shall be installed into the ground to 3 m depth, preferably by driving; the top of the casing pipe shall have provision for adding extensions at top by screw coupling; and as the surcharge construction proceeds the casing pipe is extended. This procedure ensures avoiding drilling through the surcharge already placed as well as any damage to the installed band drains. Undisturbed samples (UDS) are recovered and UCS is determined in the site laboratory (sending UDS sample to distant laboratories would result in loss of water content and

disturbance of the samples leading to erroneous values of UCS). Undisturbed samples shall be recovered at every 1.5m depth at the specified locations, so that complete strength profile of subsoil is obtained.

vii) During the placing of the surcharge and compaction, the contractor shall take utmost care so that the monitoring instruments are not damaged. Compaction by small vibratory rollers shall be done for 1.5m around the monitoring instruments and bigger rollers shall not be used near the monitoring instruments. Similarly care shall be taken that movement of dumpers does not damage the monitoring instruments.

viii) **Frequency of Observations :** The readings of the piezometers and the settlement gauges shall be recorded at the following frequency.

a) Daily reading shall be taken in stretches where filling/ surcharge operations are in progress. Weekly readings shall be taken in stretches, where no filling/ surcharge is being done.

b) Weekly readings shall be taken after the desired fill/ surcharge height is achieved, till the next stage filling commences. All data shall be recorded in a register and maintained properly.

c) The Data from the monitoring instruments provides the background for regulating the rate of placing the fill/ surcharge as well as the waiting period between stages.

ix) **Precautions against Pilferage :** The observation data would have to be recorded during construction and for three Months thereafter. It is therefore essential that the equipments are not tampered and stolen. Suitable precautions shall be taken in this regard by the contractor.

x) **Drainage of Ground Water :** The water which will come out from the subsoil through vertical drains will be accumulated at temporary ditches to be digged at nearby areas and the accumulated water will be dewatered regularly from the ditches to the outfalls as directed by the Engineer.

xi) **Certification from the manufacturer of band drain and geotextile fabric for separation and drainage :**

a) The contractor shall provide to the Engineer, a certificate stating the name of the manufacturer, product name, style number, chemical composition of the filament or yarns and other pertinent information to fully describe the material. Each roll shall be labeled or tagged to protect product identification as well as inventory and quality control.

b) The manufacturer is responsible for establishing and maintaining a quality control programme to assure compliance with the requirement of the specification. Documentation describing the quality control programme shall be made available upon request.

c) The manufacturer's certificate shall state that the furnished material meets minimum averages roll values (MARV) requirements of the specifications as evaluated under the Manufacturer's quality control programme. The certificate shall be attested by a person having legal authority to bind the Manufacturer.

314.2.3 Measurements for Payment :

i) The Geosynthetic Band Drains (or geodrain) shall be measured in liner metre of its length.

ii) The granular sand blanket shall be measured in cubic metre.

iii) The geo-synthetic fabric shall be measured in square metre of plan area of final finished work.

iv) Instrumentation and Monitoring the behaviour of sub-soil/ embankment shall be measured in number of locations.

v) The additional surcharge quantity forming part of permanent embankment shall be measured in cum.

The overlaps, patches, sewn seams and securing pins shall not to be measured.

314.2.4 Rate : Rate shall include cost of design, materials, installation, operations involved in pre-loading/ additional surcharge, dewatering, labour, plant hire, material storage and handling expenses for completing the work including submission of construction drawings and provision of specialist attendance & supervision at site for (i) geodrain; (ii) sand blanket; (iii) geofabric; (iv) instrumentation and monitoring; and (v) permanent embankment part of surcharge as described above.

314.3 Rammed Stone Columns using non-displacement method of construction

314.3.1 The design and construction of this column shall generally comply with the requirements of IS: 15284 (Part 2), including all latest amendments and specifically with the requirements of this Particular Specification. In the case of conflict between the requirements of IS: 15284 and this Particular Specification the requirements of this Particular Specification shall prevail.

314.3.2 Stone columns are columns formed from well-graded crushed stone and gravel compacted to a dense state. The size of the well graded crushed aggregate varies from 2 mm to 75 mm conforming to the gradation given below.

Size of the Crushed Aggregate	% Passing
75 mm (3")	90-100
50 mm (2")	80-90
38 mm (1.5")	55-75
20 mm (3/4")	1020
12 mm (1/2")	5-13
2 mm	5

The crushed aggregate shall be chemically inert, hard and resistant to breakage. It may be noted that stones of uniform size permit penetration of fines into the large voids thereby jeopardizing the capacity of the column and/ or its function as a vertical drain.

314.3.3 **Granular Blanket :** A compacted and well draining layer of gravel or coarse sand, of specified thickness, compacted in layers to a relative density of 75 to 80 percent shall be provided above the existing ground. This blanket shall be exposed to atmosphere at its periphery for pore water pressure dissipation.

314.3.4 **Construction and Installation Requirements :** The “Rammed Stone Columns” shall be constructed by non-displacement technique namely “Bailer and Casing Method” as given in IS:15284 (Part 1). A certain depth of stone columns at the top remains uncompacted due to absence of confinement in this region. After ensuring complete removal of slush deposited during boring operations, a minimum depth of 0.5 m, preferably 0.75 below the granular blanket shall be compacted by other suitable means such as rolling/ tamping to the specified densification criteria.

314.3.6 **Field Controls :** In the above method, the following minimum field controls shall essentially be observed.

The set criteria and the consumption of granular fill form the main quality control measures for the columns constructed by the non-displacement technique. The set criteria shall be established as given in IS 15284 (Part 1). For ascertaining the consumption of fill, the diametre of the column as formed during field trials shall be measured in its uppermost part along the four diametres and average of these observations taken as the column diametre.

314.3.7 Field Loading Tests : Initial and routine tests shall be carried out as given in IS:15284 (Part 1).

314.3.8 Recording of Data shall be done as given in IS 15284 (Part 1).

314.3.9 Load Test Results : The ultimate load capacity of single column is, with reasonable accuracy, determined form load tests. The settlement of a stone column obtained at safe/ working load from load test results on a single column shall not be directly used in forecasting the settlement of the structure unless experience form similar foundations in similar soil conditions on its settlement behaviour is available. The average settlement may be assessed on the basis of sub-soil data and loading details of the structures as a whole using the principles of soil mechanics.

314.3.10 Certification : The Contractor is responsible for establishing and maintaining a quality control programme to assure compliance with the requirements of the specifications.

314.3.11 Measurement for Payment

i) The rammed stone column shall be measured in linear metre of its compacted length.

ii) The sand blanket shall be measured in cum.

iii) The initial and routine load tests, unless otherwise specified in the contract, shall be measured in numbers and paid.

314.3.12 Rate : The rate shall include the cost of providing all materials, tools, equipment, labor, supervision and incidentals necessary to complete the work as per these specifications.

314.4 Stone Columns using vibro-replacement (vibroflot) method of construction

314.4.1 The design and construction of this column shall generally comply with the requirements of IS:15284 (Part 2), including all latest amendments and specifically with the requirements of this Particular Specification. In the case of conflict between the

requirements of IS:15284 and this Particular Specification the requirements of this Particular Specification shall prevail. The scope of work includes :

i) construction of stone columns, complete in-place including layout;

ii) furnishing crushed stone, equipment, electrical power, water and any other necessary items for stone column and its installation;

iii) Control and disposal of surface water resulting from stone column construction operations;

iv) Construction of sand (or stone) working platform and necessary access to site (this may be included under another contract);

v) Construction and removal of silt settling ponds or similar facilities as required, and the regrading of the site as required;

vi) Stockpiling and disposal of silt from the site if necessary; and

vii) Load testing of stone columns as specified

314.4.2 Stone Column with maximum compacted density shall extend to the full depth of the compressible stratum and shall be proven to reach the Dense Sand Layer/Stiff Clay Layer through the monitoring records for each column

314.4.3 The Contractor shall (i) meet all applicable laws and regulations concerning surface runoff, siltation, pollution and general disposal of the effluent from the construction of the stone columns and general site work. (ii) Construct and relocate temporary ditches, swales, banks, dams, and similar facilities as necessary to control the flow of surface water during the work. Remove them when no longer required, and regrade the affected areas for acceptable drainage as specified for site grading. (iii) Construct silt settling ponds as required in locations indicated or approved. Ensure that earth banks and water control devices are safely designed and prevent inadvertent discharge into watercourses off the site. Stockpile and dispose of all silt as approved by the Engineer. (iv) Remove settling ponds and other structures when no longer required and regrade the areas for acceptable drainage as specified for site grading.

314.4.4 Materials

a) **Stone Aggregate for Compacted Column :** The crushed stone and gravel for column backfill shall be clean, hard, angular, chemically inert, resistant to breakage and free from organic, trash, or other deleterious materials. It shall be well-graded stones of 75 mm down to 12 mm size conforming to the gradation given below. The uniformity co-efficient shall be greater than 3 and the grain size distribution curve

shall reflect well graded material. The crushing value of the stone shall not be more than 30 percent and impact value not more than 25 percent.

Size of Aggregates	% Passing
75 mm (3")	90-100
50 mm (2")	40-90
20 mm (3/4")	0-10
12 mm (1/2")	0-5

It may be noted that stones of uniform size may permit penetration of clay into the large voids thereby jeopardizing the capacity of the column and/or its function as a vertical drain

b) **Drainage Blanket :** Sand/crushed stone, which is hard, inert, resistant to chemical change and free from organic, trash, or other deleterious materials shall only be used in drainage blanket. The blanket shall be well graded and free draining granular material of thickness 50 cm or more, compacted in layers to a relative density of 75 to 80 percent. This blanket shall be exposed to atmosphere at its periphery for pore water pressure dissipation.

314.4.5 **Construction and Installation :** The stone columns shall be installed by vibroflot method given in IS 15284 (Part 1). Stones shall be fed by mechanical means i.e. use of loader/ hopper/ chute etc. The slush, muck and other loose materials at work site shall be removed/ disposed off suitably by the contractor as instructed by the Engineer. The contractor shall take adequate measures to ensure stability of bore holes made for installation of stone column.

314.4.5.1 A detailed installation procedure/method statement shall be submitted by the Contractor including:

i) Type and number of vibroflots and general method of operation including construction schedule.

ii) Mechanical arrangement for placing stones (s) around the probe point

iii) Quality control, Quality Assurance Procedure covering details on automatic recording devices to monitor and record stone consumption

iv) Type of Equipments to be deployed

v) Manpower to be engaged

vi) The proposed sequence and timing for constructing stone columns having regard to the avoidance of damage to adjacent stone columns

vii) Bar chart for the entire foundation work

314.4.5.2 Stone column installation procedure shall be as approved by the Engineer. The construction technique and probe shall be capable of producing and/or complying with the following:

i) The holes shall be close to circular.

ii) The probe and follower tubes shall be of sufficient length to reach the elevations shown on the plans. The probe, used in combination with the flow rate and available pressure to the tip jet, shall be capable of penetrating to the required tip elevation. Preboring of stiff lenses, layers or strata is permitted.

iii) The probe shall have visible external markings at one (1) foot/suitable increments to enable measurement of penetration and re-penetration depths

iv) The equipment to be used shall be instrumented with sensors and the data processed by a micro-processing unit to enable continuous monitoring and data capture of the following during construction of each stone column:

a) depth of vibrator and vibrator movements (depth of penetration)

b) power consumption (compaction effort)

314.4.5.3 Data captured shall be continuously displayed on a LCD unit and graphical output (plots of depth versus time and power consumption) generated by automated computerized recording device throughout the process of stone column installation for each point shall be submitted to the Engineer.

i) Sufficient quantity of wash water shall be provided to the tip of the probe to widen the probe hole to a diametre to allow adequate space for stone backfill placement around the probe. The flow of water from the bottom jet shall be maintained at all times during backfilling to prevent caving or collapse of the hole and to form a clean stone column. The flow rate will generally be greater as the hole is jetted in, and decrease as the stone column comes up

ii) After forming the hole, the vibrator shall be lifted up a minimum 3 m, dropped at least twice to flush the hole out. The probe shall not, however, be completely removed from the hole

iii) The column shall be formed by adding stone in lifts having each lift height between 600cm and 1000cm. The stone aggregate in each lift shall be compacted by re-penetrating it at least twice with the horizontally vibrating probe so as to densify and force the stone radially into the surrounding in-situ soil. The stone in each increment shall be re-penetrated a sufficient number of times to develop a minimum ammeter reading on the motor of at least 40 amps more than the free-standing (unloaded) ampere draw on the motor, but no less than 80 amps total

iv) Stone columns shall be installed so that each completed column will be continuous throughout its length

314.4.5.4 If erosion of upper granular working plat-form material occurs, the depressions shall be backfilled with sand/ granular material which meets the specification for the working platform. Such backfilling shall be at the Contractor’s expense. The working surface shall be cleaned at the completion of the stone column construction of all unsuitable materials washed up from the stone column holes. Such unsuitable materials include clay or silt lumps, wood fragments or other organic matter. If, in the opinion of the Engineer, these materials create “soft spots” or zones of compressibility or weakness in connection with the placement of overlying embankment materials, these unsuitable materials shall be disposed of in a manner approved by the Engineer

314.4.5.5 In the event of obstructions preventing the penetration of the vibrofloat, the Contractor shall stop work, move to another compaction point and immediately notify the Engineer. The Engineer may at his option authorize one or several of the following: (i) position the compaction point a short distance away from the original position, (ii) additional compaction points to bridge the obstruction, (iii) remove the obstruction, replace removed soils, and again jet the column hole in the indicated location or (iv) perform other removal or relocation operations.

314.4.6 **Field Controls :** In the above method, the following minimum field controls shall essentially be observed.

a) Vibroflot penetration depth including the depth of embedment in firm strata.

b) Monitoring of volume of backfill added to obtain an indication of the densities achieved, and

c) Monitoring of ammeter or hydraulic pressure gauge readings to verify that the maximum possible density has been achieved in case of vibrofloted columns.

314.4.7 Recording of Data shall be done as given in IS 15284 (Part 1).

314.4.8 Field Loading Tests

314.4.8.1 The Initial load tests shall be performed at a trial test site to evaluate the load-settlement behaviour of the soil-stone column system. The tests shall be conducted on a single and also on a group of minimum three columns in accordance with IS:15284 (Part-1). The number of initial tests shall be as follows:

Single column tests – 1 test per 500 or part thereof stone columns.

Three column group tests – 1 test per 1000 or part thereof stone columns.

314.4.8.2 The Routine load tests shall be carried out on a single job column in accordance with IS:15284 (Part-1). The job columns shall be loaded for a test load of 1.1 times the design load intensity with kentledge minimum 1.3 times the design load pattern. The number of routine tests shall be as follows:

Single column tests – 1 test per 500 or part thereof stone columns.

314.4.8.3 The test load shall be applied at increments of 1/10th of the design load upto a maximum of 1.5 times the design load. Each load stage shall be maintained till the settlement rate is less than 0.1 mm/30 min.

314.4.8.4 The test load shall be maintained for a minimum period of 24 hours. The ultimate load on the stone column shall be determined by double tangent diagram. The test load shall be removed in five/six stages. Each unloading stage shall be maintained till the rebound attains a rate of 2.0 mm/30 min.

314.4.8.5 Safe and efficient working of the loading arrangements is entirely the Contractor’s responsibility and any impediment resulting in the failure of the test arrangement may debar the contractor from payment for the test. Alternatively, it may make the contractor liable to repeat the test on separate column/columns without any extra cost to the Engineer.

314.4.8.6 The Engineer shall approve the location of this test and the construction of stone columns shall, to the satisfaction of the Engineer, be carried out using the same procedure as all the rest of the stone columns on site. The stone columns under the test shall be a part of a larger stone column group. The interpretation of the results shall be free from ambiguity and shall be subject to the Engineers approval. No works shall proceed unless the Contractor shall satisfy the Engineer beyond reasonable doubt that the performance of the stabilized soil material will be compliant with the Specification.

314.4.9 Tolerances

314.4.9.1 Setting Out : Setting out shall be carried out from reference lines and points shown in the drawings. Immediately before installation of the stone columns, the stone column positions shall be marked with suitable identifiable markers.

314.4.9.2 Position : No vibration center or stone column shall be more than 150 mm off its correct center location in any direction at the working platform level as shown on the approved plans.

314.4.9.3 Verticality : Stone Columns shall be constructed as vertical as possible. The axis of the stone column shall not be inclined from the vertical by more than 1h: 20v as indicated by the tilt of vibrator and follower tubes.

314.4.10 Personnel : The Contractor shall employ personnel having atleast 4 - 5 years experience in the construction of stone columns.

314.4.11 Certification : The Contractor is responsible for establishing and maintaining a quality control programme to assure compliance with the requirements of the specifications.

314.4.12 Measurements for payment :

i) The stone column by vibroflot method shall be measured in linear metre of its compacted length.

ii) The sand blanket shall be measured in cum.

iii) The initial and routine load tests, unless otherwise specified in the contract, shall be measured in numbers and paid.

314.4.13 Rate : The rate shall include the cost of providing all materials, tools, equipment, labor, supervision and incidentals necessary to complete the work as per these specifications.

400

Sub-Bases,Bases (Non-Bituminous) and Shoulders

401 GRANULAR SUB-BASE

401.1 Scope

This work shall consist of laying and compacting well-graded material on prepared subgrade in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as sub-base or lower sub-base and upper sub-base (termed as sub-base hereinafter) as necessary according to lines, grades and cross-sections shown on the drawings or as directed by the Engineer.

401.2 Materials

401.2.1 The material to be used for the work shall be natural sand, crushed gravel, crushed stone, or combination thereof depending upon the grading required. The material shall be free from organic or other deleterious constituents and shall conform to the quality standards as prescribed in the specifications.

Table 400-1 prescribes four gradings for Granular Sub-Base (GSB). Gradings I and II in Table 400-1 are well graded granular sub-base materials. These can be used at locations where drainage requirement are not predominant. Gradings III and IV are gap graded and addresses to the concern of the drainage requirements. These can be used at location experiencing heavy rainfall, flooding etc. Cases where GSB is to be provided in two layers, it is recommended to adopt either grading III or grading IV for lower layer and either grading I or grading II for upper layer. Minimum thickness of lower layer at locations where drainage requirements are predominant shall not be less than 200 mm. The grading to be adopted for a project shall be as specified in the Contract.

401.2.2 Physical requirements: The material shall have a 10 percent fines value of 50kN or more (for sample in soaked condition) when tested in compliance with IS:2386 (Part IV) 1963. The water absorption value of the coarse aggregate shall be determined as per IS:2386 (Part 3). If this value is greater than 2 percent, the soundness test shall be carried out on the material delivered to site as per IS:383. For Gradings II and IV materials, the CBR shall be determined at the density and moisture content likely to be developed in the field.

401.3 Strength of Sub-Base

It shall be ensured prior to actual execution that the material to be used in the sub-base satisfies the requirements of CBR and other physical requirements when compacted and finished.

When directed by the Engineer, this shall be verified by performing CBR tests in the laboratory as required on specimens remoulded at field dry density and moisture content.

Table 400-1 Grading for Granular Sub-base Materials

IS Sieve Designation	Percent by weight passing the IS sieve			
	Grading I	Grading II	Grading III	Grading IV
75.0 mm	100	—	100	—
53.0 mm	80-100	100	100	
26.5 mm	55 –90	70-100	55-75	50-80
9.50 mm	35-65	50-80		
4.75 mm	25 – 55	40-65	10-30	15-35
2.36 mm	20- 40	30-50		
0.425 mm	10-15	10- 15		
0.075 mm	<5	< 5	< 5	< 5
CBR Value (Minimum)	30	25	30	25

Note: The material passing 425 micron (0.425 mm) sieve for all the gradings when tested according to IS:2720 (Part 5) shall have liquid limit and plasticity index not more than 25 and 6 percent respectively.

401.4 Construction Operations

401.4.1 Preparation of subgrade : Immediately prior to the laying of sub-base, the subgrade already finished to Clause 301 or 305 as applicable shall be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water, if necessary and rolled with two passes of 80–100 kN smooth wheeled roller.

401.4.2 Spreading and compacting : The sub-base material of grading specified in the Contract shall be spread on the prepared subgrade with the help of a motor grader of adequate capacity, its blade having hydraulic controls suitable for initial adjustment and for maintaining the required slope and grade during the operation or other means as approved by the Engineer.

When the sub-base material consists of combination of materials mentioned in Clause 401.2.1, mixing shall be done mechanically. Mixing shall be done in a separate yard by pugmill or other approved mechanical means so as to issue homogenous & uniform mix.

Moisture content of the loose material shall be checked in accordance with IS:2720 (Part 2) and suitably adjusted by sprinkling additional water from a truck mounted or trailer mounted water tank and suitable for applying water uniformly and at controlled quantities to variable widths of surface or other means approved by the Engineer so that, at the time of compaction, it is from 1 percent above to 2 percent below the optimum moisture content corresponding to IS:2720 (Part 8). While adding water, due allowance shall be made for evaporation losses. After water has been added, the material shall be processed by mechanical or other approved means until the layer is uniformly wet.

Immediately thereafter, rolling shall start. If the thickness of the compacted layer does not exceed 100 mm, a smooth wheeled roller of 80 to 100 kN weight may be used. For a compacted single layer upto 200 mm the compaction shall be done with the help of a vibratory roller of minimum 80 to 100 kN static weight with plain drum or pad foot-drum or heavy pneumatic tyred roller of minimum 200 to 300 kN weight having a minimum tyre pressure of 0.7 MPa or equivalent capacity roller capable of achieving the required compaction. Rolling shall commence at the lower edge and proceed towards the upper edge longitudinally for portions having unidirectional crossfall and super-elevation shall commence at the edges and progress towards the centre for portions having crossfall on both sides.

Each pass of the roller shall uniformly overlap not less than one-third of the track made in the preceding pass. During rolling, the grade and crossfall (camber) shall be checked and any high spots or depressions which become apparent, corrected by removing or adding fresh material. The speed of the roller shall not exceed 5 km per hour.

Rolling shall be continued till the density achieved is at least 98 percent of the maximum dry density for the material determined as per IS:2720 (Part 8). The surface of any layer of material on completion of compaction shall be well closed, free from movement under compaction equipment and from compaction planes, ridges, cracks or loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of layer and re-compacted.

401.5 Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Clause 902. Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

401.6 Arrangements for Traffic

During the period of construction, arrangements for the traffic shall be provided and maintained in accordance with Clause 112.

401.7 Measurements for Payment

Granular sub-base shall be measured as finished work in position in cubic metres.

The protection of edges of granular sub-base extended over the full formation as shown in the drawing shall be considered incidental to the work of providing granular sub-base and as such no extra payment shall be made for the same.

401.8 Rate

The Contract unit rate for granular sub-base shall be payment in full for carrying out the required operations including full compensation for:

i) making arrangements for traffic to Clause 112 except for initial treatment to verges, shoulders and construction of diversions;

ii) furnishing all materials to be incorporated in the work including all royalties, fees, rents where applicable with all leads and lifts;

iii) all labour, tools, equipment and incidentals to complete the work to the Specifications;

iv) carrying out the work in part widths of road where directed; and

v) carrying out the required tests for quality control.

402 LIME TREATED SOIL FOR IMPROVED SUB-GRADE/SUB-BASE

402.1 Scope

This work shall consist of laying and compacting an improved sub-grade/lower sub-base of soil treated with lime on prepared sub-grade in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer. Lime treatment is generally effective for soils which contain a relatively high percentage of clay and silty clay.

402.2 Materials

402.2.1 **Soil** : Except when otherwise specified, the soil used for stabilization shall be the local clayey soil having a plasticity index greater than 8.

402.2.2 **Lime** : Lime for lime-soil stabilization work shall be commercial dry lime slaked at site or pre-slaked lime delivered to the site in suitable packing. Unless otherwise permitted by the Engineer, the lime shall have purity of not less than 70 percent by weight of Quick-lime (CaO) when tested in accordance with IS:1514. Lime shall be properly stored to avoid prolonged exposure to the atmosphere and consequent carbonation which would reduce its binding properties.

402.2.3 **Quantity of lime in stabilized mix** : Quantity of lime to be added as percentage by weight of the dry soil shall be as specified in the Contract. The quantity of lime used shall be related to its calcium oxide content which shall be specified. Where the lime of different calcium oxide content is to be used, its quantity shall be suitably adjusted to the approval of the Engineer so that equivalent calcium oxide is incorporated in the work. The mix design shall be done to arrive at the appropriate quantity of lime to be

added, having due regard to the purity of lime, the type of soil, the moisture-density relationship, and the design CBR/Unconfined Compressive Strength (UCS) value specified in the Contract. The laboratory CBR/UCS value shall be at least 1.5 times the minimum field value of CBR/UCS stipulated in the Contract.

402.2.4 Water : The water to be used for lime stabilisation shall be clean and free from injurious substances. Potable water shall be preferred.

402.3 Construction Operations

402.3.1 Weather limitations : Lime-soil stabilisation shall not be done when the air temperature in the shade is less than 10^0 C.

402.3.2 Degree of pulverisation : For lime stabilisation, the soil before addition of stabilizer, shall be pulverized using agricultural implements like disc harrows (only for low volume roads) and rotavators to the extent that it passes the requirements set out in Table 400-2 when tested in accordance with the method described in Appendix 3.

Table 400-2 Soil Pulverisation Requirements for Lime Stabilisation

IS Sieve designation	Minimum percent by weight passing the IS Sieve
26.5 mm	100
5.6 mm	80

402.3.3 Equipment for construction : Stabilised soil sub-bases shall be constructed by mix-in-place method of construction or as otherwise approved by the Engineer. Manual mixing shall be permitted only where the width of laying is not adequate for mechanical operations, as in small-sized jobs.

The equipment used for mix-in-place construction shall be a rotavator or similar approved equipment capable of pulverizing and mixing the soil with additive and water to specified degree to the full thickness of the layer being processed, and of achieving the desired degree of mixing and uniformity of the stabilized material. If so desired by the Engineer, trial runs with the equipment shall be carried out to establish its suitability for work.

The thickness of any layer to be stabilized shall be not less than 100 mm when compacted. The maximum thickness can be 200 mm, provided the plant used is accepted by the Engineer.

402.3.4 Mix-in-place method of construction : Before deploying the equipment, the soil after it is made free of undesirable vegetation or other deleterious matter shall be

spread uniformly on the prepared subgrade in a quantity sufficient to achieve the desired compacted thickness of the stabilised layer. Where single-pass equipment is to be employed, the soil shall be lightly rolled at the discretion of the Engineer.

The equipment used shall either be of single-pass or multiple pass type. The mixers shall be equipped with an appropriate device for controlling the depth of processing and the mixing blades shall be maintained or reset periodically so that the correct depth of mixing is obtained at all times.

With single-pass equipment the forward speed of the machine shall be so selected in relation to the rotor speed that the required degree of mixing, pulverisation and depth of processing is obtained. In multiple-pass processing, the prepared sub-grade shall be pulverised to the required depth with successive passes of the equipment and the moisture content adjusted to be within prescribed limits mentioned hereinafter. The blending or stabilizing material shall then be spread uniformly and mixing continued with successive passes until the required depth and uniformity of processing have been obtained.

The mixing equipment shall be so set that it cuts slightly into the edge of the adjoining lane processed previously so as to ensure that all the material forming a layer has been properly processed for the full width.

402.3.5 Construction with manual means : Where manual mixing is permitted, the soil from borrow areas shall first be freed of all vegetation and other deleterious mater and placed on the prepared subgrade. The soil shall then be pulverized by means of crow-bars, pick axes or other means approved by the Engineer.

Water in requisite quantities may be sprinkled on the soil for aiding pulverisation. On the pulverized soil, the blending material(s) in requisite quantities shall be spread uniformly and mixed thoroughly by working with spades or other similar implements till the whole mass is uniform. After adjusting the moisture content to be within the limits mentioned later, the mixed material shall be leveled up to the required thickness so that it is ready to be rolled.

402.3.6 Addition of lime : Lime may be mixed with the prepared material either in slurry form or dry state at the option of the Contractor with the approval of the Engineer.

Dry lime shall be prevented from blowing by adding water to the lime or other suitable means selected by the Contractor, with the approval of the Engineer.

The tops of windrowed material may be flattened or slightly trenched to receive the lime. The distance to which lime may be spread upon the prepared material ahead of the mixing operation shall be determined by the Engineer.

No traffic other than the mixing equipment shall be allowed to pass over the spread lime until after completion of mixing.

Mixing or remixing operations, regardless of equipment used, shall continue until the material is free of any white streaks or pockets of lime and the mixture is uniform.

Non-uniformity of colour reaction, when the treated material is tested with the standard phenolphthalein alcohol indicator, will be considered evidence of inadequate mixing.

402.3.7 Moisture content for compaction : The moisture content at compaction checked vide IS:2720 (Part 2) shall neither be less than the optimum moisture content corresponding to IS:2720 (Part 8) nor more than 2 percent above it.

402.3.8 Rolling : Immediately after spreading, grading and levelling of the mixed material, compaction shall be carried out with approved equipment preceded by a few passes of lighter rollers if necessary. Rolling shall commence at edges and progress towards the centre, except at super elevated portions where it shall commence at the inner edge and progress towards the outer edge. During rolling, the surface shall be frequently checked for grade and crossfall (camber) and any irregularities corrected by loosening the material and removing/adding fresh material. Compaction shall continue until the density achieved is at least 98 percent of the maximum dry density for the material determined in accordance with IS:2720 (Part 8).

Care shall be taken to see that the compaction of lime stabilised material is completed within three hours of its mixing or such shorter period as may be found necessary in dry weather.

During rolling it shall be ensured that roller does not bear directly on hardened or partially hardened treated material previously laid other than what may be necessary for achieving the specified compaction at the joint. The final surface shall be well closed, free from movement under compaction planes, ridges, cracks or loose material. All loose or segregated or otherwise defective areas shall be made good to the full thickness of the layer and recompacted.

402.3.9 Curing : The sub-base course shall be suitably cured for a minimum period of 7 days after which subsequent pavement courses shall be laid to prevent the surface from drying out and becoming friable. No traffic of any kind shall ply over the completed sub-base unless permitted by the Engineer.

402.4 Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Clause 902.

Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

402.5 Strength

When lime is used for improving the subgrade, the soil-lime mix shall be tested for its CBR value. When lime stabilized soil is used in a sub-base, it shall be tested for unconfined compressive strength (UCS) at 7 days. In case of variation from the design CBR/UCS, in situ value being lower, the pavement design shall be reviewed based on the actual CBR/ UCS values. The extra pavement thickness needed on account of lower CBR/UCS value shall be constructed by the Contractor at his own cost.

402.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be provided and maintained in accordance with Clause 112.

402.7 Measurements for Payment

Stabilised soil sub-base shall be measured as finished work in position in cubic metres.

402.8 Rate

The Contract unit rate for lime stabilised soil sub-base shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 401.8 (i) to (v).

403 CEMENT TREATED SOIL SUB-BASE/BASE

403.1 Scope

This work shall consist of laying and compacting a sub-base/base course of soil treated with cement on prepared subgrade/sub-base, in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer.

403.2 Materials

403.2.1 Material to be stabilised : The material used for cement treatment shall be soil including sand and gravel, laterite, kankar, brick aggregate, crushed rock or slag or any combination of these. For use in a sub-base course, the material shall have a grading shown in Table 400-3(a). It shall have a uniformity coefficient not less than 5, capable of producing a well-closed surface finish. For use in a base course, the material shall be sufficiently well graded to ensure a well-closed surface finish and have a grading within the range given in Table 400-3. If the material passing 425 micron sieve is plastic, it shall have a liquid limit not greater than 45 percent and a plasticity index not greater than 20 percent determined in accordance with IS:2720 (Part 5). The physical requirements

for the material to be treated with cement for use in a base course shall be same as for Grading I Granular Sub-base, Clause 401.2.2.

403.2.2 Cement : Cement for stabilization shall either be ordinary portland cement, portland slag cement or portland puzzolana cement and shall comply with the requirements of IS:269, 455 or 1489 respectively.

Table 400-3 Grading Limits of Material for Stabilisation with Cement

IS sieve size	Percentage by mass passing
	Sub-Base/Base Within the range
53.00 mm	100
37.5 mm	95 – 100
19.0 mm	45 – 100
9.5 mm	35 – 100
4.75 mm	25 – 100
600 micron	8 – 65
300 micron	5 – 40
75 micron	0 – 10

403.2.3 Lime : If needed for pre-treatment of highly clayey soils, Clause 402.2.2 shall apply.

403.2.4 Quantity of cement in stabilised mix : The quantity of cement to be added as percent by weight of the dry soil shall be specified in the Contract. Also if lime is used as pretreatment for highly clayey soils, the quantity as percent by weight of dry soil shall be specified in the Contract. The mix design shall be done on the basis of 7 day unconfined compressive strength (UCS) and/or durability test under 12 cycles of wet-dry conditions. The laboratory strength values shall be at least 1.5 times the minimum field UCS value stipulated in the Contract.

403.2.5 Water : The water to be used for cement stabilization shall be clean and free from injurious substances. Potable water shall be preferred.

403.3 Construction Operations

403.3.1 Weather limitations : Stabilisation shall not be done when the air temperature in the shade is less than 10°C.

403.3.2 Degree of pulverisation : For stabilisation, the soil before addition of stabilizer, shall be pulverised, where necessary, to the extent that it passes the requirements

as set out in Table 400-4 when tested in accordance with the method described in Appendix 3.

Table 400-4 Soil Pulverisation Requirements for Cement Stabilisation

IS sieve Designation	Minimum per cent by weight passing the IS sieve
26.5 mm	100
5.6 mm	80

403.3.3 Clauses 402.3.3 to 402.3.5 shall apply as regards spreading and mixing the stabilizer except that cement or lime plus cement as the case may be, shall be used as the stabilizing material.

403.3.4 **Moisture content for compaction** : The moisture content at compaction checked vide IS:2720 (Part 2) shall not be less than the optimum moisture content corresponding to IS:2720 (Part 8) nor more than 2 per cent above it.

403.3.5 **Rolling** : Clause 402.3.8 shall apply except that care shall be taken to see that the compaction of cement stabilised material is completed within two hours of its mixing or such shorter period as may be found necessary in dry weather.

403.3.6 **Curing** : The sub-base/base course shall be suitably cured for 7 days. Subsequent pavement course shall be laid soon after to prevent the surface from drying out and becoming friable. No traffic of any kind shall ply over the completed sub-base unless permitted by the Engineer.

403.4 Surface Finish and Quality Control of Works

The surface finish of construction shall conform to the requirements of Clause 902.

403.5 Strength

Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

Cement treated soil sub-base/base shall be tested for the unconfined compressive strength (UCS) value at 7 days, actually obtained in-situ. In case of variation from the design UCS, in-situ value being on lower side, prior to proceeding with laying of base/surface course on it, the pavement design shall be reviewed for actual UCS value. The extra pavement thickness needed on account of lower UCS shall be constructed by the Contractor at his own cost.

403.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be provided and maintained in accordance with Clause 112.

403.7 Measurements for Payment

Stabilised soil sub-base/base shall be measured as finished work in position in cubic metres.

403.8 Rate

The Contract unit rate for cement treated soil sub-base/base with pretreatment with lime if required shall be payment in full for carrying out required operations including full compensation for all components listed in Clause 401.8 (i) to (v).

404 WATER BOUND MACADAM SUB-BASE/BASE

404.1 Scope

This work shall consist of clean crushed aggregates mechanically interlocked by rolling and bonding together with screening, binding material where necessary and water laid on a properly prepared subgrade/sub-base/base or existing pavement, as the case may be and finished in accordance with the requirements of these Specifications and in close conformity with the lines, grades, cross-sections and thickness as per approved plans or as directed by the Engineer. This specification is meant for repairs and minor works of widening nature, and also at locations where it is not feasible to lay WMM.

404.2 Materials

404.2.1 Coarse aggregates : Coarse aggregates shall be either crushed or broken stone, crushed slag, overburnt (Jhama) brick aggregates or any other naturally occurring aggregates such as kankar and laterite of suitable quality. Materials other than crushed or broken stone and crushed slag shall be used in sub-base courses only. If crushed gravel /shingle is used, not less than 90 percent by weight of the gravel/shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces. The aggregates shall conform to the physical requirements set forth in Table 400-5. The type and size range of the aggregate shall be specified in the Contract or shall be as specified by the Engineer. If the water absorption value of the coarse aggregate is greater than 2 percent, the soundness test shall be carried out on the material delivered to site as per IS:2386 (Part 5).

Table 400-5 Physical Requirements of Coarse Aggregates for Water Bound Macadam for Sub-base/Base Courses

S.No.	Test	Test Method	Requirements
1.	Los Angeles Abrasion value	IS: 2386 (Part 4)	40 percent (Max)
	Aggregate Impact value	IS: 2386 (Part-4) or IS:5640*	30 percent (Max)
2.	Combined Flakiness and Elongation Indices (Total) **	IS:2386 (Part-1)	40 percent (Max)

* Aggregates which get softened in presence of water shall be tested for Impact value under wet conditions in accordance with IS:5640.

** The requirement of flakiness index and elongation index shall be enforced only in the case of crushed broken stone and crushed slag.

404.2.2 Crushed or broken stone : The crushed or broken stone shall be hard, durable and free from excess flat, elongated, soft and disintegrated particles, dirt and other deleterious material.

404.2.3 Crushed slag : Crushed slag shall be made from air-cooled blast furnace slag. It shall be of angular shape, reasonably uniform in quality and density and generally free from thin, elongated and soft pieces, dirt or other deleterious materials. The weight of crushed slag shall not be less than 11.2 kN per m^3 and the percentage of glossy material shall not be more than 20. It should also comply with the following requirements:

i)	Chemical stability	:	To comply with requirements of appendix of BS:1047.
ii)	Sulphur content	:	Maximum 2 percent
iii)	Water absorption	:	Maximum 10 percent

404.2.4 Overburnt (Jhama) brick aggregates : Jhama brick aggregates shall be made from overburnt bricks or brick bats and be free from dust and other objectionable and deleterious materials. This shall be amount only for road stretch when traffic is low.

404.2.5. Grading requirement of coarse aggregates : The coarse aggregates shall conform to one of the Gradings given in Table 400-6 as specified, provided, however, the use of Grading No.1 shall be restricted to sub-base courses only.

Table 400-6 Grading Requirements of Coarse Aggregates

Grading No.	Size Range	IS Sieve Designation	Per cent by weight passing
1.	63 mm to 45 mm	75 mm	100
		63 mm	90 – 100
		53 mm	25 – 75
		45 mm	0 – 15
		22.4 mm	0 – 5
2.	53 mm to 22.4 mm	63 mm	100
		53 mm	95 – 100
		45 mm	65 – 90
		22.4 mm	0 – 10
		11.2 mm	0 – 5

Note: The compacted thickness for a layer shall be 75 mm.

404.2.6 Screenings : Screenings to fill voids in the coarse aggregate shall generally consist of the same material as the coarse aggregate. However, where permitted, predominantly non-plastic material such as moorum or gravel (other than rounded river borne material) may be used for this purpose provided liquid limit and plasticity index of such material are below 20 and 6 respectively and fraction passing 75 micron sieve does not exceed 10 percent.

Screenings shall conform to the grading set forth in Table 400-7. The consolidated details of quantity of screenings required for various grades of stone aggregates are given in Table 400-8. The table also gives the quantities of materials (loose) required for 10 m^2 for sub-base/base compacted thickness of 75 mm.

The use of screenings shall be omitted in the case of soft aggregates such as brick metal, kankar, laterites, etc. as they are likely to get crushed to a certain extent under rollers.

404.2.7 Binding material : Binding material to be used for water bound macadam as a filler material meant for preventing ravelling shall comprise of a suitable material approved by the Engineer having a Plasticity Index (PI) value of less than 6 as determined in accordance with IS:2720 (Part-5).

The quantity of binding material where it is to be used, will depend on the type of screenings. Generally, the quantity required for 75 mm compacted thickness of water bound macadam will be 0.06–0.09 m^3 per 10 m^2.

Table 400-7 Grading For Screenings

Grading Classification	Size of Screenings	IS Sieve Designation	Per cent by weight passing the sieve
A	13.2 mm	13.2 mm 11.2 mm 5.6 mm 180 micron	100 95 – 100 15 - 35 0 –10
B	1.2 mm	11.2 mm 5.6 mm 180 micron	100 90 – 100 15 – 35

Table 400-8 Approximate Quantities of Coarse Aggregates and Screenings Required for 75 mm Compacted Thickness of Water Bound Macadam (WBM) Sub-base/Base Course for 10m^2 Area

Classifi-cation	Size Range	Compacted thickness	Loose Qty.	Screenings			
				Stone Screening		Crushable type such as Moorum or Gravel	
				Grading Classifi-cation & Size	For WBM Sub-base/ base course (Loose quantity)	Grading Classi- fication & Size	Loose Qty.
Grading 1	63 mm to 45 mm	75 mm	0.91 to 1.07 m^3	Type A 13.2 mm	0.12 to 0.15 m^3	Not uniform	0.22 to 0.24 m^3
-do-	-do-	-do-	-do-	Type B 11.2 mm	0.20 to 0.22 m^3	-do-	-do-
Grading 2	53 mm to 22.4 mm	75 mm	-do-	-do-	0.18 to 0.21 m^3	-do-	-do-

The above mentioned quantities should be taken as a guide only, for estimation of quantities for construction etc.

Application of binding materials may not be necessary when the screenings used are of crushable type such as moorum or gravel.

404.3 Construction Operations

404.3.1 Preparation of base : The surface of the sub-grade/sub-base/base to receive the water bound macadam course shall be prepared to the specified grade and camber and cleaned of dust, dirt and other extraneous material. Any ruts or soft yielding places shall be corrected in an approved manner and rolled until firm surface is obtained.

Where the WBM is to be laid on an existing metalled road, damaged area including depressions and potholes shall be repaired and made good with the suitable material. The existing surface shall be scarified and re-shaped to the required grade and camber before spreading the coarse aggregate for WBM.

As far as possible, laying water bound macadam course over existing bituminous layer may be avoided since it will cause problems of internal drainage of the pavement at the interface of two courses. It is desirable to completely pick out the existing thin bituminous wearing course where water bound macadam is proposed to be laid over it.

404.3.2 Inverted choke/sub surface drainage layer : If water bound macadam is to be laid directly over the sub-grade, without any other intervening pavement course, a 25 mm course of screenings (Grading B) or coarse sand shall be spread on the prepared sub-grade before application of the aggregates is taken up. In case of a fine sand or silty or clayey sub-grade, it is advisable to lay 100 mm insulating layer of screening or coarse sand on top of fine grained soil, the gradation of which will depend upon whether it is intended to act as a drainage layer as well. As a preferred alternative to inverted choke, appropriate geosynthetics performing functions of separation and drainage may be used over the prepared sub-grade as directed by the Engineer. Section 700 shall be applicable for use of geosynthetics.

404.3.3 Lateral confinement of Aggregates : For construction of WBM, arrangement shall be made for the lateral confinement of aggregates. This shall be done by building adjoining shoulders along with WBM layers. The practice of constructing WBM in a trench section excavated in the finished formation must be completely avoided.

Where the WBM course is to be constructed in narrow widths for widening of an existing pavement, the existing shoulders should be excavated to their full depth and width up to the sub-grade level except where widening specifications envisages laying of a stablised sub-base using in-situ operations in which case the same should be removed only up to the sub-base level.

404.3.4 Spreading coarse aggregates : The coarse aggregates shall be spread uniformly and evenly upon the prepared sub-grade/sub-base in the required quantities from the stockpiles to proper profile by using templates placed across the road about 6 m apart, in such quantities that the thickness of each compacted layer is not more than 75 mm. In no case shall these be dumped in heaps directly on the area where these are to be

laid nor shall their hauling over a partly completed base be permitted. Wherever possible, approved mechanical devies such as aggregate spreader shall be used to spread the aggregates uniformly so as to minimize the need for manual rectification afterwards.

No segregation of coarse or fine aggregates shall be allowed and the coarse aggregates, as spread shall be of uniform gradation with no pockets of fine material.

The surface of the aggregates spread shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregates as may be required. The surface shall be checked frequently with a straight edge while spreading and rolling so as to ensure a finished surface as per approved drawings.

The coarse aggregates shall not normally be spread more than 3 days in advance of the subsequent construction operations.

404.3.5 Rolling : Immediately following the spreading of the coarse aggregates, rolling shall be started with three wheeled power rollers of 80 to 100 kN capacity or tandem or vibratory rollers of 80 to 100 kN static weight. The type of roller to be used shall be approved by the Engineer based on trial run.

Except on superelevated portions where the rolling shall proceed from inner edge to the outer, rolling shall begin from the edges gradually progressing towards the center. First the edge/edges shall be compacted with roller running forward and backward. The roller shall then move inward parallel to the center line of the road, in successive passes uniformly overlapping preceding tracks by at least one-half width.

Rolling shall be continued until the road metal is thoroughly keyed and the creaping of stone ahead of the roller is no longer visible. During rolling, slight sprinkling of water may be done, if necessary. Rolling shall not be done when the sub-grade is soft or yielding or when it causes a wave-like motion in the sub-grade or sub-base course.

The rolled surface shall be checked transversely with templates and longitudinally with 3 m straight edge. Any irregularities, exceeding 12 mm, shall be corrected by loosening the surface, adding or removing necessary amount of aggregates and re-rolling until the entire surface conforms to the desired camber and grade. In no case shall the use of screenings be permitted to make up depressions.

Material, which gets crushed excessively during compaction or becomes segregated, shall be removed and replaced with suitable aggregates.

404.3.6 Application of screenings : After the coarse aggregates have been rolled to Clause 404.3.5, screenings to completely fill the interstices shall be applied gradually over the surface. These shall not be damp or wet at the time of application. Dry rolling shall be done while the screenings are being spread so that vibrations of the roller cause

them to settle into the voids of the coarse aggregates. The screenings shall not be dumped in piles but be spread uniformly in successive thin layers either by the spreading motions of hand shovels or by mechanical spreaders, or directly from tipper with suitable grit spreading arrangement. Tipper operating for spreading the screenings shall be equipped with pneumatic tyres and operated so as not to disturb the coarse aggregates.

The screenings shall be applied at a slow and uniform rate (in three or more applications) so as to ensure filling of all voids. This shall be accompanied by dry rolling and brooming with mechanical brooms, hand brooms or both. In no case shall the screenings be applied so fast and thick as to form cakes or ridges on the surface in such a manner as would prevent filling of voids or prevent the direct bearing of the roller on the coarse aggregates. The spreading, rolling, and brooming of screenings shall be carried out in only such lengths of the road which could be completed within one day's operation.

404.3.7 Sprinkling of water and grouting : After application of screenings, the surface shall be copiously sprinkled with water, swept and rolled. Hand brooms shall be used to sweep the wet screenings into voids and to distribute them evenly. The sprinkling, sweeping and rolling operation shall be continued, with additional screenings applied as necessary until the coarse aggregates have been thoroughly keyed, well-bonded and firmly set in its full depth and a grout has been formed of screenings. Care shall be taken to see that the sub-base or sub-grade does not get damaged due to the addition of excessive quantities of water during construction.

In case of lime treated soil sub-base, construction of water bound macadam on top of it can cause excessive water to flow down to the lime treated sub-base before it has picked up enough strength (is still "green") and thus cause damage to the sub-base layer. The laying of water bound macadam layer in such cases shall be done after the sub-base attains adequate strength, as directed by the Engineer.

404.3.8 Application of binding material : After the application of screenings in accordance with Clauses 404.3.6 and 404.3.7, the binding material where it is required to be used (Clause 404.2.7) shall be applied successively in two or more thin layers at a slow and uniform rate. After each application, the surface shall be copiously sprinkled with water, the resulting slurry swept in with hand brooms, or mechanical brooms to fill the voids properly, and rolled during which water shall be applied to the wheels of the rollers if necessary to wash down the binding material sticking to them. These operations shall continue until the resulting slurry after filling of voids, forms a wave ahead of the wheels of the moving roller. In case the aggregates are of a soft variety it would be preferred to replace binder material with an equivalent amount of additional screenings.

404.3.9 Setting and drying : After the final compaction of water bound macadam course, the pavement shall be allowed to dry overnight. Next morning hungry spots shall be filled with screenings or binding material as directed, lightly sprinkled with water if

necessary and rolled. No traffic shall be allowed on the road until the macadam has set. The Engineer shall have the discretion to stop hauling traffic from using the completed water bound macadam course, if in his opinion it would cause excessive damage to the surface.

The compacted water bound macadam course shall be allowed to completely dry and set before the next pavement course is laid over it.

404.4 Surface Finish and Quality Control of Work

404.4.1 The surface finish of construction shall conform to the requirements of Clause 902.

404.4.2 Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

404.4.3 The water bound macadam work shall not be carried out when the atmospheric temperature is less than 10°C in the shade.

404.4.4 **Reconstruction of defective macadam** : The finished surface of water bound macadam shall conform to the tolerances of surface regularity as prescribed in Clause 902. However, where the surface irregularity of the course exceeds the tolerances or where the course is otherwise defective due to sub-grade soil mixing with the aggregates, the course to its full thickness shall be scarified over the affected area, reshaped with added material or removed and replaced with fresh material as applicable and re-compacted. The area treated shall not be less than 10 sq.m. In no case shall depressions be filled up with screenings or binding material.

404.5 Arrangements for Traffic.

During the period of construction, the arrangements for traffic shall be done as per Clause 112.

404.6 Measurements for Payment

Water bound macadam shall be measured as finished work in position in cubic metres.

404.7 Rate

The Contract unit rate for water bound macadam sub-base/base course shall be payable in full for carrying out the required operations including full compensation for all components listed in Clause 401.8 (i) to (v), including arrangement of water used in the work as approved by the Engineer.

405 CRUSHED CEMENT CONCRETE SUB-BASE/BASE

405.1 Scope

This work shall consist of breaking and crushing the damaged cement concrete slabs and re-compacting the same as sub-base/base course in one or more layers. Where specified, it shall also include treating the surface of the top layer with a penetration coat of bitumen. The work shall be performed on such widths and lengths as may be specified, in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as otherwise directed by the Engineer.

405.2 Materials

405.2.1 Coarse aggregates : Coarse aggregates for this work shall be broken cement concrete slabs crushed to a size not exceeding 75 mm and as far as possible, conforming to one of the gradings given in Table 400-7.

405.2.2 Key aggregates : Key aggregate for the penetration coat shall consist of crushed stone, crushed gravel, shingle or other stones. It shall be clean, strong, durable, of fairly cubical shape and free of disintegrated pieces, organic or other deleterious matter and adherent coating. The aggregates shall be hydrophobic and of low porosity.

The aggregate shall be 11.2 mm size defined as 100 percent passing through 13.2 mm sieve and retained on 5.6 mm sieve and shall satisfy the physical requirements set forth in Table 500-3.

405.2.3 Binder : Binder for the penetration coat for the top layer shall be bitumen of a suitable grade, as directed by the Engineer and satisfying the requirements of IS:73, 217 or 454, as applicable or any approved cutback or emulsion, satisfying the requirements of IS:8887.

405.3 Construction Operations

405.3.1 General : Crushed cement concrete sub-base/base course may be constructed in one or two layers, depending upon the thickness of the concrete slabs dismantled and crushed. The thickness of each layer shall, however, not exceed 100 mm in case of sub-base and 75 mm in case of base course.

The course shall be constructed as water bound macadam to Clause 404, using crushed cement concrete as coarse aggregates except that no screenings or binding material need be applied. Where specified, the top layer shall be treated with a penetration coat of binder described in Clause 405.3.2.

405.3.2 Application of penetration coat over the top layer : Before the application of the penetration coat, the surface shall be cleaned of dust, dirt and other foreign matter, using mechanical broom or any other equipment specified by the Engineer. Dust removed in the process shall be blown off with the help of compressed air.

The binder shall be heated to the temperature appropriate to the grade of bitumen used and sprayed on the dry surface in a uniform manner at the rate of 25 kg per 10 m^2 area in terms of the residual bitumen with the help of either self-propelled or towed bitumen pressure sprayer with self-heating arrangement and spray nozzle capable of spraying bitumen at specified rates and temperatures so as to provide a uniform unbroken spread of bitumen. Excessive deposits of binder caused by stopping or starting of the sprayer or through leakage or any other cause shall be suitably corrected.

Immediately after the application of binder, the key aggregates, in a clean and dry state shall be spread uniformly on the surface at the rate of 0.13 m^3 per 10 m^2 area, preferably by means of a mechanical gritter, capable of spreading aggregates uniformly at specified rates or otherwise manually with the approval of the Engineer, so as to cover the surface completely. Immediately after the application of the key aggregates, the entire surface shall be rolled to Clause 506.3.8.

405.4 Surface Finish and Quality Control of Work

The surface finish and control on the quality of materials and works shall be exercised by the Engineer in accrodance with section 900.

405.5 Arrangements for Traffic

During the period of construction, arrangement for traffic shall be done as per Clause 112.

405.6 Measurements for Payment

Breaking the existing cement concrete pavement slabs, crushing and recompacting the slab material as sub-base/base course shall be measured as a single item in terms of the volume of sub-base/base laid in position in cubic metres.

Penetration coat shall be measured as finished work in square metres.

405.7 Rate

405.7.1 The Contract unit rate for crushed cement concrete sub-base/base course shall be payment in full for carrying out the required operations including full compensation for:

i) making arrangements for traffic to Clause 112 except for initial treatment to verges/shoulders and construction of diversions;

ii) breaking the cement concrete slabs, crushing, sieving and recompacting the slab material as sub-base/base course;

iii) all labour, tools, equipment and incidentals to complete the work to the Specifications; and

iv) carrying out the work in part widths of road where directed.

405.7.2 The Contract unit rate for penetration coat shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 504.8.

406 WET MIX MACADAM SUB-BASE/BASE

406.1 Scope

This work shall consist of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared sub-grade/sub-base/base or existing pavement as the case may be in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as necessary to lines, grades and cross-sections shown on the approved drawings or as directed by the Engineer.

The thickness of a single compacted Wet Mix Macadam layer shall not be less than 75 mm. When vibrating or other approved types of compacting equipment are used, the compacted depth of a single layer of the sub-base course may be upto 200 mm with the approval of the Engineer.

406.2 Materials

406.2.1 Aggregates

406.2.1.1 Physical requirements : Coarse aggregates shall be crushed stone. If crushed gravel/shingle is used, not less than 90 percent by weight of the gravel/shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces. The aggregates shall conform to the physical requirements set forth in Table 400-9.

If the water absorption value of the coarse aggregate is greater than 2 percent, the soundness test shall be carried out on the material delivered to site as per IS:2386 (Part-5).

406.2.1.2 Grading requirements : The aggregates shall conform to the grading given in Table 400-10.

Table 400-9 Physical Requirements of Coarse Aggregates for Wet Mix Macadam for Sub-base/Base Courses

S. No.	Test	Test Method	Requirements
1.	Los Angeles Abrasion value	IS:2386 (Part-4)	40 percent (Max.)
	Aggregate Impact value	IS:2386 (Part-4) or IS:5640	30 percent (Max.)
2.	Combined Flakiness and Elongation indices (Total)	IS:2386 (Part-1)	40 percent (Max.)*

* To determine this combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particles be separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The values of flakiness index and elongation index so found are added up.

Table 400-10 Grading Requirements of Aggregates for Wet Mix Macadam

IS Sieve Designation	Per cent by weight passing the IS Sieve	
	Grade 1 layer thickness ≥ 100mm	Grade 2<100 mm
53.00 mm	100	
45.00 mm	95 – 100	
26.50 mm	–	100
22.40 mm	60 – 80	50-100
11.20 mm	40 – 60	-
4.75 mm	25 – 40	35-55
2.36 mm	15 – 30	-
600.00 micron	8 – 22	10-30
75.00 micron	0 – -5	2-5

Material finer than 425 micron shall have Plasticity Index (PI) not exceeding 6.

The final gradation approved within these limits shall be graded from coarse to fine and shall not vary from the low limit on one sieve to the high limit on the adjacent sieve or vice versa.

406.3 Construction Operations

406.3.1 Preparation of base : Clause 404.3.1 shall apply.

406.3.2 Provision of lateral confinement of aggregates : While constructing wet mix macadam, arrangement shall be made for the lateral confinement of wet mix. This shall be done by laying materials in adjoining shoulders along with that of wet mix macadam layer and following the sequence of operations described in Clause 407.4.1.

406.3.3 Preparation of mix : Wet Mix Macadam shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and forced/ positive mixing arrangement like pugmill or pan type mixer of concrete batching plant. The plant shall have following features:

i) Cold aggregates with minimum four bin feeders with variable speed motor

ii) Vibrating screen for removal of oversize aggregates

iii) Conveyor Belt

iv) Controlled system for addition of water

v) Forced/positive mixing arrangement like pug-mill or pan type

vi) Anti-segregation hydraulically operated gob/surge hopper

vii) Centralized control panel for sequential operation of various devices and precise process control

viii) Safety devices

Optimum moisture for mixing shall be determined in accordance with IS:2720 (Part-8) after replacing the aggregate fraction retained on 22.4 mm sieve with material of 4.75 mm to 22.4 mm size. While adding water, due allowance should be made for evaporation losses. However, at the time of compaction, water in the wet mix should not vary from the optimum value by more than agreed limits. The mixed material should be uniformly wet and no segregation should be permitted.

406.3.4 Spreading of mix : Immediately after mixing, the aggregates shall be spread uniformly and evenly upon the prepared sub-grade/sub-base/base in required quantities. In no case shall these be dumped in heaps directly on the area where these are to be laid nor shall their hauling over a partly completed stretch be permitted.

The mix may be spread by a paver finisher. The paver finisher shall be self-propelled, of repute make, proven design and adequate capacity with following features:-

i) Tractor unit shall have crawler tracks or pneumatic tyre.

ii) Racks provide greater traction and suitable to work on soft or loose sub-bases and laying large width up to 10 m or more. Wheeled paver is faster and normally preferred to work on hard surfaces with width up to 8 m.

iii) Material distribution system comprising of hopper, two conveyor belts each working independently, conveyor speed adjustable with limit switches and auger system easily capable of raising and lower; to provide a smooth uninterrupted material flow for different layer thicknesses from the tipper to the screed.

iv) Hydraulically operated telescopic screed for paving width upto to 8.5 m and fixed screed beyond this. The screed shall have tamping and vibrating arrangement for initial compaction of the layer.

v) The drive shall be hydrostatic with infinite variable speed.

vi) Automatic leveling control system with electronic sensing device to maintain mat thickness and cross slope of mat during laying procedure.

In exceptional cases where it is not possible for the paver to be utilized, mechanical means like motor grader may be used with the prior approval of the Engineer. The motor grader shall be capable of spreading the material uniformly all over the surface. For portions where mechanical means cannot be used, manual means as approved by the Engineer shall be used only in restricted areas.

The surface of the aggregate shall be carefully checked with templates and all high or low spots remedied by removing or adding aggregate as may be required. The layer may be tested by depth blocks during construction. No segregation of larger and fine particles should be allowed. The aggregates as spread should be of uniform gradation with no pockets of fine materials.

The Engineer may permit manual mixing and /or laying of wet mix macadam where small quantity of wet mix macadam is to be executed. Manual mixing/laying in inaccessible/ remote locations and in situations where use of machinery is not feasible can also be permitted. Where manual mixing/laying is intended to be permitted, the same shall be indicated in the Contract.

406.3.5 **Compaction** : After the mix has been laid to the required thickness, grade and crossfall/camber the same shall be uniformly compacted to the full depth with suitable

roller. If the thickness of single compacted layer does not exceed 200 mm, a smooth wheel roller of 80 to 100kN weight may be used. For a compacted single layer upto 200 mm, the compaction shall be done with the help of vibratory roller of minimum static weight of 80 to 100 kN with on amplitude not exceeding 0.7 mm or equivalent capacity roller. The speed of the roller shall not exceed 5 km/h.

In portions having unidirectional cross fall/superelevation, rolling shall commence from the lower edge and progress gradually towards the upper edge. Thereafter, roller should progress parallel to the center line of the road, uniformly over-lapping each preceding track by at least one-third width until the entire surface has been rolled. Alternate trips of the roller shall be terminated in stops at least 1 m away from any preceding stop.

In portions in camber, rolling should begin at the edge with the roller running forward and backward until the edges have been firmly compacted. The roller shall then progress gradually towards the center parallel to the center line of the road uniformly overlapping each of the preceding track by at least one-third width until the entire surface has been rolled.

Any displacement occurring as a result of reversing of the direction of a roller or from any other cause shall be corrected at once as specified and/or removed and made good.

Along forms, kerbs, walls or other places not accessible to the roller, the mixture shall be thoroughly compacted with mechanical tampers or a plate compactor. Skin patching of an area without scarifying the surface to permit proper bonding of the added material shall not be permitted.

Rolling should not be done when the sub-grade is soft or yielding or when it causes a wave-like motion in the sub-base/base course or sub-grade. If irregularities develop during rolling which exceed 12 mm when tested with a 3 m straight edge, the surface should be loosened and premixed material added or removed as required before rolling again so as to achieve a uniform surface conforming to the desired grade and crossfall. In no case shall the use of unmixed material be permitted to make up the depressions.

Rolling shall be continued till the density achieved is at least 98 percent of the maximum dry density for the material as determined by the method outlined in IS:2720 (Part-8).

After completion, the surface of any finished layer shall be well-closed, free from movement under compaction equipment or any compaction planes, ridges, cracks and loose material. All loose, segregated or otherwise defective areas shall be made good to the full thickness of the layer and recompacted.

406.3.6 **Setting and drying** : After final compaction of wet mix macadam course, the road shall be allowed to dry for 24 hours.

406.4 Opening to Traffic

No vehicular traffic of any kind should be allowed on the finished wet mix macadam surface.

406.5 Surface Finish and Quality Control of Work

406.5.1 Surface evenness : The surface finish of construction shall conform to the requirements of Clause 902.

406.5.2 Quality control : Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

406.6 Rectification of Surface Irregularity

Where the surface irregularity of the wet mix macadam course exceeds the permissible tolerances or where the course is otherwise defective due to sub-grade soil getting mixed with the aggregates, the full thickness of the layer shall be scarified over the affected area, re-shaped with added premixed material or removed and replaced with fresh premixed material as applicable and recompacted in accordance with Clause 406.3. The area treated in the aforesaid manner shall not be less than 5 m long and 2 m wide. In no case shall depressions be filled up with unmixed and ungraded material or fines.

406.7 Arrangement for Traffic

During the period of construction, arrangements for traffic shall be done as per Clause 112.

406.8 Measurements for Payment

Wet mix macadam shall be measured as finished work in position in cubic metres.

406.9 Rate

The Contract unit rate for wet mix macadam shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 401.8.

407 SHOULDERS, ISLANDS AND MEDIANS

407.1 Scope

The work shall consist of constructing shoulder (hard/paved/earthen with brick or stone block edging) on either side of the pavement, median in the road dividing the carriageway

into separate lanes and islands for channelising the traffic at junctions in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer.

407.2 Materials

Shoulder on either side of the road may be of selected earth/granular material/paved conforming to the requirements of Clause 305/401 and the median may be of selected earth conforming to the requirements of Clause 305.

Median/Traffic islands shall be raised and kerbed at the perimeter and the enclosed area filled with earth and suitably covered with grass turf/shrubs as per Clause 307 and/or paved as per Clause 409.3.4 or 409.3.5.

Paved shoulders shall consist of sub-base, base and surfacing courses, as shown in the drawings and materials for the same shall conform to relevant Specifications of the corresponding items. Where paved or hard shoulders are not provided, the pavement shall be provided with brick/stone block edgings as shown in the drawings. The brick shall conform to Clause 1003 of these Specifications. Stone blocks shall conform to Clause 1004 of these Specifications and shall be of size 225 mm x 110 mm x 75 mm.

407.3 Size of Shoulders/Medians/Islands

Shoulder (earthen/hard/paved)/median/traffic island dimensions shall be as shown on the drawings or as directed by the Engineer.

407.4 Construction Operations

407.4.1 Shoulders : The sequence of operations shall be such that the construction of paved shoulder is done in layers each matching the thickness of adjoining pavement layer. Only after a layer of pavement and corresponding layers in paved and earth shoulder portion have been laid and compacted, the construction of next layer of pavement and shoulder shall be taken up.

Where the materials in adjacent layers are different, these shall be laid together and the pavement layer shall be compacted first. The corresponding layer in paved shoulder portion shall be compacted thereafter, which shall be followed by compaction of each shoulder layer. The adjacent layers having same material shall be laid and compacted together.

In all cases where paved shoulders have to be provided along side of existing carriageway, the existing shoulders shall be excavated in full width and to the required depth as per Clause 301.3.7. Under no circumstances, box cutting shall be done for construction of shoulders.

Compaction requirement of earthen shoulder shall be as per Table 300-2. In the case of bituminous courses, work on shoulder (earthen/hard/paved), shall start only after the pavement course has been laid and compacted.

During all stages of shoulder (earthen/hard/paved) construction, the required crossfall shall be maintained to drain off surface water.

Regardless of the method of laying, all shoulder construction material shall be placed directly on the shoulder. Any spilled material dragged on to the pavement surface shall be immediately removed, without damage to the pavement, and the area so affected thoroughly cleaned.

407.4.2 Median and Islands : Median and islands shall be constructed in a manner similar to shoulder up to the road level. Thereafter, the median and islands, if raised, shall be raised at least 300 mm by using kerb stones of approved material and dimensions and suitably finished and painted as directed by the Engineer. If not raised, the median and islands shall be differentiated from the shoulder/pavement as the case may be, as directed by the Engineer. The confined area of the median and islands shall be filled with local earth or granular material or any other approved material and compacted by plate compactor/power rammer. The confined area after filling with earth shall be turfed with grass or planted with shrubs and in case of granular fill it can be finished with tiles/slabs as directed by the Engineer.

407.4.3 Brick/stone block edging : The brick/stone blocks shall be laid on edge, with the length parallel to the transverse direction of the road. They shall be laid on a bed of 25 mm sand, set carefully rolled into position by a light roller and made flush with the finished level of the pavement.

407.5 Surface Finish and Quality Control of Works

The surface finish of construction shall conform to the requirements of Clause 902. Control on the quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

407.6 Measurements for Payment

Shoulder (earthen/hard/paved), island and median construction shall be measured as finished work in position as below:

i) For excavation in cu.m.
ii) For earthwork/granular fill in cu.m.

iii) For sub-base, base, surfacing courses in units as for respective items
iv) For kerb in running meters
v) For turfing and tile/slab finish in sq.m.
vi) For brick/stone block edging in sq.m.

407.7 Rate

The Contract unit rate for shoulder (hard/paved/earthen with brick or stone block edging), island and median construction shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 401.8 (i) to (v) as applicable. The rate for brick/stone block edging shall include the cost of sand cushion.

408. CEMENT CONCRETE KERB AND KERB WITH CHANNEL

408.1 Scope

This work shall consist of constructing cement concrete kerbs and kerbs with channel in the central median and/or along the footpaths or separators in conformity with the lines, levels and dimensions as specified in the drawings or as directed by the Engineer.

408.2 Materials

Kerbs and kerb with channel shall be provided in cement concrete of Grade M 20 in accordance with Section 1700 of these Specifications.

408.3 Type of Construction

These shall be cast-in-situ construction with suitable kerb casting machine in all situations except at locations where continuous casting with equipment is not practicable. In those locations precast concrete blocks shall be used.

408.4 Equipment

A continuous kerb casting equipment of adequate capacity and controls, capable of laying the kerbs in required cross-sections and producing a well-compacted mass of concrete free of voids and honeycombs, shall be used.

408.5 Construction Operations

408.5.1 Kerb shall be laid on firm foundation of minimum 150 mm thickness of cement concrete of M 15 grade cast in-situ or on extended width of pavement. The foundation shall have a projection of 50 mm beyond the kerb stone. Before laying the foundation of lean concrete, the base shall be leveled and slightly watered to make it damp.

408.5.2 In the median portions in the straight reaches, the kerb shall be cast in continuous lengths. In the portions where footpath is provided and/or the slope of the carriageway is towards median (as in case of superelevated portion), there shall be sufficient gap/recess left in the kerb to facilitate drainage openings.

408.5.3 After laying the kerbs and just prior to hardening of the concrete, saw cut grooves shall be provided at 5 m intervals up to FRL or as specified by the Engineer.

408.5.4 Kerbs on the drainage ends such as along the footpath or the median in superelevated portions, shall be cast with monolithic concrete channels as indicated in drawings. The slope of the channel towards drainage pipes shall be ensured for efficient drainage of the road surface.

408.5.5 Vertical and horizontal tolerances with respect to true line and level shall be +6 mm.

408.6 Measurements for Payment

Cement concrete kerb/kerb with channel shall be measured in linear metre for the complete item of work.

Foundation of kerb, where separately provided shall be measured in linear metre for complete item of work.

408.7 Rate

The Contract unit rates for cement concrete kerb/kerb with channel and foundation for kerb shall be payment in full compensation for furnishing all materials, labour, tools, equipment for construction and other incidental cost necessary to complete the work.

409 FOOTPATHS AND SEPARATORS

409.1 Scope

The work shall consist of constructing footpaths and/or separators at locations as specified in the drawings or as directed by the Engineer.

The lines, levels and dimensions shall be as per the drawings. The scope of the work shall include provision of all drainage arrangements as shown in the drawings or as directed by the Engineer.

409.2 Materials

The footpaths and separators shall be constructed with any of the following types:

a) Cast-in-situ cement concrete of Grade M 20 as per Section 1700 of the Specifications.

b) Precast cement concrete blocks/tiles of Grade M 20 as per Section 1700 of the Specifications. The minimum thickness of the cement concrete block/tile shall be 25 mm and minimum size shall be 300 mm x 300 mm.

c) Natural stone slab cut and dressed from stone of good and sound quality, uniform in texture, free from defects and at least equal to a sample submitted by the Contractor and approved by the Engineer. The minimum thickness of the natural stone slab shall be 25 mm and minimum size shall be 300 mm x 300 mm.

409.3 Construction Operations

409.3.1 Drainage pipes below the footpath originating from the kerbs shall be first laid in the required slope and connected to the drains/sumps/storm water drain/drainage chutes as per provisions of the drawings, or as specified.

409.3.2 Portion on back side of kerbs shall be filled and compacted with granular sub-base material as per Clause 401 of the Specifications in specified thickness.

409.3.3 The base shall be prepared and finished to the required lines, levels and dimensions as indicated in the drawing with the following:

a) Minimum 150 mm thick, compacted granular sub-base material as per Clause 401 of the Specifications.

b) Minimum 25 mm thick cement concrete of Grade M 15.

Over the prepared base, precast concrete blocks/tiles/natural stone slabs and/or cast-in-situ slab shall be set/laid as described in Clauses 409.3.4 and 409.3.5.

409.3.4 **Precast cement concrete blocks/tiles/natural stone slabs** : The blocks/tiles/slabs shall be set on a layer of average 12 mm thick cement-sand mortar (1:3) laid on prepared base in such a way that there is no rocking. The gaps between the blocks/tiles/slabs shall not be more than 12 mm and shall be filled with cement-sand mortar (1:3).

409.3.5 **Cast-in-situ cement concrete** : The minimum thickness of the cement concrete shall be 25 mm and it shall be cast on the prepared base in panels of specified size in a staggered manner. Construction joints shall be provided as per Section 1700 of the Specifications.

409.4 Measurements for Payment

Footpaths and separators shall be measured in sq.m between inside of kerbs.

409.5 Rate

Contract unit rates shall be inclusive of full compensation of all labour, materials, tools, equipment and incidentals to construction of footpaths. Cost of providing pipes and arrangement for their discharge into appropriate drainage channels shall be incidental to the construction of footpaths.

410 CRUSHER-RUN MACADAM BASE

410.1 Scope

This work shall consist of furnishing, placing and compacting crushed stone aggregate sub-base and base courses constructed in accordance with the requirements set forth in these Specifications and in conformity with the lines, grades, thickness and cross-sections shown on the plans or as directed by the Engineer.

410.2 Materials

The material to be used for the work shall be crushed rock. If crushed gravel/shingle is used, not less than 90 percent by weight of the gravel/shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces. It shall be free from any organic matter and other deleterious substances and shall be of such nature that it can be compacted readily under watering and rolling to form a firm, stable base. The aggregates shall conform to the grading and quality requirements given in Tables 400-11 and 400-12.

At the option of the Contractor, the grading for either 53 mm maximum size or 37.5 mm maximum size shall be used, except that once a grading is selected, it shall not be changed without the Engineer's approval.

410.3. Construction Operations

410.3.1 Preparation of subgrade : Any ruts, deformations or soft yielding places which occur in the sub-base or sub-grade shall be corrected and compacted to the required density before the aggregate base course is placed thereon.

410.3.2 Spreading, watering, mixing and compaction : The aggregate shall be uniformly deposited on the approved subgrade by means of hauling vehicle with or without spreading devices. Aggregate will be distributed over the surface to the depth specified on the plans or as directed by the Engineer.

Table 400.11 Aggregate Grading Requirements

Sieve Size	Per cent passing by weight	
	53 mm max. size	37.5 mm max. size
63 mm	100	
45 mm	87 – 100	100
22.4 mm	50 – 85	90 – 100
5.6 mm	25 – 45	35 – 55
710 mm	10 – 25	10 – 30
90 mm	2 – 5	2 – 5

Table 400.12 Physical Requirements of Coarse Aggregates for Crusher-run Macadam Base

	Test	Test Method	Requirements
1.	Los Angeles Abrasion value	IS:2386 (Part-4)	40 maximum
	Aggregate Impact value	IS:2386 (Part-4) or IS:5640	30 maximum
2.	Combined Flakiness and Elongation Indices (Total)	IS:2386 (Part-1)	40 maximum**
3	*Water absorption	IS:2386 (Part-3)	2 percent maximum
4.	Liquid Limit of material passing 425 micron	IS:2720 (Part-5)	25 maximum
5.	Plasticity Index of material passing 425 micron	IS:2720 (Part-5)	6 maximum

* If the water absorption is more than 2 percent, soundness test shall be carried out as per IS:2386 (Part-5)

** To determine this combined proportion, the flaky stone from a representative sample should first be separated out. Flakiness index is weight of flaky stone metal divided by weight of stone sample. Only the elongated particles be separated out from the remaining (non-flaky) stone metal. Elongation index is weight of elongated particles divided by total non-flaky particles. The value of flakiness index and elongation index so found are added up.

After the base course material has been deposited, it shall be thoroughly blade-mixed to full depth of the layer by alternately blading the entire layer to the center and back to the edges of the road. It shall then be spread and finished to the required cross-section by means of a motor grader.

Water shall be applied prior to and during all blading and processing operations to moisten the material sufficiently to prevent segregation of the fine and coarse particles. Water shall be applied in sufficient amounts during construction to assist in compaction.

Compaction shall commence immediately after the spreading operation. If the thickness of single compacted layer does not exceed 100 mm, a smooth wheel roller of 80 to 100 kN weight may be used. For a compacted single layer upto 200 mm, compaction shall be done with the help of vibratory roller of minimum static weight of 80 to 100 kN or equivalent capacity. The speed of the roller shall not exceed 5 km/h. Each layer of material shall be compacted to not less than 98 percent of the maximum density as determined by IS:2720 (Part-8).

410.4 Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Clause 902.

Control on the quality of materials and work shall be exercised by the Engineer in accordance with Section 900.

410.5 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be done in accordance with Clause 112.

410.6 Measurements for Payment

Crusher-run macadam base shall be measured as finished work in position in cubic metres.

410.7 Rate

The Contract unit rate for crusher run macadam base shall be payment in full for carrying out the required operations including full compensation for all components as in Clause 401.8 (i) to (v).

Base and Surface Course

500

Materials for Structures

501 GENERAL REQUIREMENTS FOR BITUMINOUS PAVEMENT LAYERS

501.1 General

Bituminous pavement courses shall be made using the materials described in the Specifications.

The use of machinery and equipment mentioned in various Clauses of these Specifications is mandatory. Details of the machinery and equipment are available in the Manual for Construction and Supervision of Bituminous Works. The equipment mandatory for any particular project shall be in accordance with the Contract Specifications for that project.

501.2 Materials

501.2.1 Binder : The binder shall be an appropriate type of bituminous material complying with the relevant Indian Standard (IS), as defined in the appropriate Clauses of these Specifications, or as otherwise specified herein. The choice of binder shall be stipulated in the Contract or by the Engineer. Where viscosity grades of bitumen are specified, they are referred to by a designation in accordance with IS:73. Where Modified Binder is specified, the provision of IS:15462 shall apply.

501.2.2. Coarse Aggregates: The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on the 2.36 mm sieve. They shall be clean, hard, durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious matter. Where the Contractor's selected source of aggregates has poor affinity for bitumen, as a condition for the approval of that source, the bitumen shall be treated with approved anti-stripping agents, as per the manufacturer's recommendations, without additional payment to the Contractor. Before approval of the source, the aggregates shall be tested for stripping.

The aggregates shall satisfy the physical requirements set forth in the individual relevant clause for the material in question.

Where crushed gravel is proposed for use as aggregate for bituminous concrete, not less than 95 percent by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces. However for use in other (LBM, BM, DBM, etc.) specifications not less than 90 percent by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractures faces.

501.2.3 Fine Aggregates: Fine aggregates shall consist of crushed or naturally occurring material, or a combination of the two, passing 2.36 mm sieve and retained on the 75 micron sieve. They shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter. Natural sand shall not be allowed in

binder and wearing courses. However, natural sand upto 50 percent of the fine aggregates may be allowed in base courses. Fine aggregates shall have a sand equivalent not less than 50 when tested in accordance with the requirement of IS:2720 Part 37. The plasticity index of the fraction passing 0.425 mm shall not exceed 4 when tested in accordance with IS:2720 Part 5.

501.2.4 Source of material : The source of all materials propose to be used on the project by the Contractor shall be tested to the satisfaction of and receive express approval of the Engineer. The Engineer may from time to time withdraw approval of a specific source, or attach conditions to the existing approval. Any change in aggregate source for bituminous mixes, will require a new mix design, and laying trials, where the mix is based on a job mix design. Stockpiles from different sources, approved or otherwise, shall be kept separate, such that there is no contamination between one material and another. Each source submitted for approval shall contain material sufficient for at least 5 days work.

501.3 Mixing

Pre-mixed bituminous materials, including bituminous macadam, dense bituminous macadam, bituminous concrete, etc. shall be prepared in a hot mix plant of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregates. Appropriate mixing temperatures are given in Table 500-15 of these Specifications. The difference in temperature between the binder and aggregate should at no time exceed 14°C. In order to ensure uniform quality of the mix and better coating of aggregates, the hot mix plant shall be calibrated from time to time. The essential features of the hot mix plants are given in Annexure A of IRC:27.

If a continuous mixing plant is to be used for mixing the bituminous bound macadam, the Contractor must demonstrate by laboratory analysis that the cold feed combined grading is within the grading limits specified for that bituminous bound material. In the case of a designed job mix, the bitumen and filler content shall be derived using this combined grading. Further details are available in the IRC Manual for Construction and Supervision of Bituminous Works.

501.4 Transporting

Bituminous materials shall be transported in clean insulated and covered vehicles. An asphalt release agent, such as soap or lime water, which does not adversely affect the bituminous mixes may be applied to the interior of the vehicle to prevent sticking and to facilitate discharge of the material.

501.5 Laying

501.5.1 Weather and seasonal limitations: Laying shall be suspended:

- In presence of standing water on the surface;
- When rain is imminent and during rains, fog or dust storm;
- When the base / binder course is damp;
- When the air temperature on the surface on which it is to be laid is less than 10°C for mix with conventional bitumen as binder and is less than 15°C for mix with modified bitumen as binder;
- When the wind speed at any temperature exceeds the 40 km per per hr at 2 m height.

501.5.2 Cleaning of surface : The surface on which the bituminous work is to be laid shall be cleaned of all loose and extraneous matter by means of a mechanical broom or any other approved equipment/method as specified in the contract. The use of a high pressure air jet from a compressor to remove dust or loose matter shall be available full time at the site, unless otherwise specified in the Contract.

501.5.3 Spreading : Prior to spreading the mix, the base shall be prepared by carrying out all or some of the operations as per Clause 501.8 depending upon the site conditions. Except in areas where paver cannot get access, bituminous materials shall be spread, leveled and tamped by an approved self-propelled paving machine preferably with sensor. As soon as possible after arrival at site, the materials shall be supplied continuously to the paver and laid without delay. The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously. The travel rate of the paver, and its method of operations, shall be adjusted to ensure an even and uniform flow of bituminous material across the screed, free from dragging, tearing and segregation of the material. In areas with restricted space (such as confined space, foot base, irregular shape and wearing thickness, approaches to expansion joints, etc.) where paver cannot be used, the material shall be spread, raked and leveled with suitable hand tools by trained staff. The minimum thickness of material laid in each paver pass shall be in accordance with the minimum values given in the relevant parts of these Specifications. When laying binder course or wearing course approaching an expansion joint of a structure, machine laying shall stop 300 mm short of the joint. The remainder of the pavement up to the joint, and the corresponding area beyond it, shall be laid by hand, and the joint or joint cavity shall be kept clear of surfacing material.

Bituminous material, with a temperature greater than 145°C, shall not be laid or deposited on bridge deck water-proofing systems, unless precautions against heat damage have been approved by the Engineer.

501.5.4 Cleanliness and overlaying: Bituminous material shall be kept clean and uncontaminated. The only traffic permitted run on bituminous material to be overlaid shall be that engaged in laying and compacting the next course or, where a binder course is to be sealed or surface dressed, that engaged on such surface treatment. Should any bituminous material become contaminated, the Contractor shall make it good to the satisfaction of the Engineer, in compliance with Clause 501.8.

Binder course material shall not remain uncovered by either the wearing course or surface treatment, whichever is specified in the Contract, for more than three consecutive days after being laid. The Engineer may extend this period, by the minimum amount of time necessary, because of weather conditions or for any other reason. If the surface of the base course is subjected to traffic or not covered within three days, a tack coat shall be applied as directed by the Engineer.

501.6 Compaction

Bituminous materials shall be laid and compacted in layers, which enable the specified thickness, surface level, regularity requirements and compaction to be achieved.

Compaction of bituminous materials shall commence as soon as possible after laying. Compaction shall be substantially completed before the temperature falls below the minimum rolling temperatures stated in the relevant part of these Specifications. Rolling of the longitudinal joints shall be done immediately behind the paving operation. After this, rolling shall commence at the edges and progress towards the center longitudinally except that on super elevated and unidirectional cambered portions, it shall progress from the lower to the upper edge parallel to the center line of the pavement. Rolling shall continue until all roller marks have been removed from the surface. All deficiencies in the surface after laying shall be made good by the attendants behind the paver, before initial rolling is commenced. The initial or breakdown rolling shall be done with 8–10 tonne dead weight smooth-wheeled rollers. The intermediate rolling shall be done with 8–10 tonne dead weight or vibratory roller or with a pneumatic tyred roller of 12 to 15 tonne weight having nine wheels, with a tyre pressure of at least 5.6 kg/sq.cm. The finish rolling shall be done with 6 to 8 tonne smooth wheeled tandem rollers.

Where compaction is to be determined by density of cores, the requirements to prove the performance of rollers shall apply in order to demonstrate that the specified density can be achieved. In such cases the Contractor shall nominate the plant, and the method by which he intends to achieve the specified level of compaction and finish at temperatures above the minimum specified rolling temperature. Laying trials shall then demonstrate the acceptability of the plant and method used.

Bituminous materials shall be rolled in a longitudinal direction, with the driven rolls nearest the paver. The roller shall first compact material adjacent to joints and then work from the

lower to the upper side of the layer, overlapping on successive passes by at least one-third of the width of the rear roll or, in the case of a pneumatic-tyred roller, at least the nominal width of 300 mm.

In portions with super-elevated and uni-directional camber, after the edge has been rolled, the roller shall progress from the lower to the upper edge.

Rollers should move at a speed of not more than 5 km per hour. The roller shall not be permitted to stand on pavement which has not been fully compacted, and necessary precautions shall be taken to prevent dropping of oil, grease, petrol or other foreign matter on the pavement either when the rollers are operating or standing. The wheels of rollers machine shall be in good working order, to prevent the mixture from adhering to the wheels. Only sufficient moisture to prevent adhesion between the wheels of rollers and the mixture should be used. Surplus water shall not be allowed to stand on the partially compacted pavement.

501.7 Joints

a) Where joints are made, the material shall be fully compacted and the joint made flush in one of the following ways; All joints shall be cut vertical to the full thickness of the previously laid mix. All loosened material shall be discarded and the vertical face be coated with any viscosity grade bitumen, or cold applied emulsified bitumen. While spreading the material along the joint the material spread shall overlap 25 mm to 50 mm on the previously laid mix beyond the vertical face of the joint. The thickness of the loose overlap material should be approximately a quarter more than the final compacted thickness. The overlapped mix should be dragged back to the hot lane so that the roller can press the small excess into the hot side of the joint to obtain a high joint density.

b) By using two or more pavers in echelon, where this is practicable and in sufficient proximity for adjacent widths to be fully compacted by continuous rolling.

All joints shall be offset at least 300 mm from parallel joints in the layer beneath or as directed, and in a layout approved by the Engineer. Joints in the wearing course shall coincide with either the lane edge or the lane marking, which ever is appropriate. Longitudinal joints shall not be situated in wheel track zones.

For transverse joints method a) above shall apply. Transverse joints in the successive and adjoining layers shall have a minimum offset of 2 meters.

501.8 Preparation of Surface

501.8.1 Scope : This work shall consist of preparing an existing granular or black-topped surface bituminous course. The work shall be performed on such widths and lengths as shown on the drawings or as instructed by the Engineer. The existing surface shall be firm and clean, and treated with Prime or Tack coat as shown on the drawings as otherwise stated in the Contract.

501.8.2 Materials

501.8.2.1 For scarifying and re-laying the granular surface : The material used shall be coarse aggregates salvaged from the scarification of the existing granular base course supplemented by fresh coarse aggregates and screenings so that aggregates and screenings thus supplemented correspond to Clause 404: Water Bound Macadam or Clause 406: Wet Mix Macadam.

501.8.2.2 For patching potholes and sealing cracks : Where the existing surface to be overlaid is bituminous, any existing potholes and cracks shall be repaired and sealed in accordance with Clauses 3004.2 and 3004.3, or as directed by the Engineer.

501.8.2.3 For profile corrective course : A profile corrective course for correcting the existing pavement profile shall be laid to varying thickness as shown on the Drawings, or as indicated in the Contract Documents. The profile corrective course shall be laid to tolerances and densities as specified for wearing course in a single layer, or base course, if it is to be covered with a wearing course layer.

501.8.2.4 Profile corrective course and its application : The type of material for use as profile corrective course shall be as shown on the drawings or as directed by the Engineer. Where it is to be laid as part of the overlay/ strengthening course, the profile corrective course material shall be of the same specification as that of the overlay/ strengthening course. However, if provided as a separate layer, it shall be of the specification and details given in the contract drawings.

i) Any high spots in the existing surface shall be removed by a milling machine or other approved method, and all loose material shall be removed to the satisfaction of the Engineer.

ii) Where the maximum thickness of profile corrective course will be not more than 40 mm, the profile corrective course shall be constructed as an integral part of the overlay course. In other cases, the profile corrective course shall be constructed as a separate layer, adopting such construction procedures and using such equipment as approved by the Engineer, to lay the specified type of material, to thickness and tolerance as specified for the course to be provided.

501.8.3 Construction Operations

501.8.3.1 Preparing existing granular surface : Where the existing surface is granular, all loose materials shall be removed, and the surface lightly watered where the profile corrective course to be provided as a separate layer is also granular. Where the profile corrective course of bituminous material is to be laid over the existing granular surface, the latter shall, after removal of all loose material, be primed in accordance with Clause 502.

The surface finish of all granular layers on which bituminous works are to be placed, shall, unless otherwise specifically instructed by the Engineer, be free from dust. All such layers must be capable of being swept, after the removal of any non-integral loose material, by means of a mechanical broom, without shedding significant quantities of material and dust removed by air jet, washing, or other means approved by the Engineer.

After cleaning the surface shall be correct to line and level, within the tolerances specified for base course.

501.8.3.2 Scarifying existing bituminous surface : Where specified or shown on the drawings, the existing bituminous layer in the specified width shall be removed with care and without causing undue disturbance to the underlying layer, by a suitable method approved by the Engineer. After removal, all loose and disintegrated material, the underlying layers which might have been disturbed should be suitable reworked and compacted to line and level. After supplementing the base material as necessary with suitable fresh stone, the compacted finished surface shall be primed in accordance with Clause 502. Reusable materials shall be stacked as directed by the Engineer within 1000m of their origin.

501.8.3.3 Patching of potholes and sealing of cracks : Where the existing surface to be overlaid is bituminous, any existing potholes and cracks shall be repaired and sealed in accordance with Clauses 3004.2 and 3004.3, or as directed by the Engineer.

501.8.3.4 Laying the profile corrective course

501.8.3.4.1 Laying on granular base : After preparing the granular surface in accordance with Clauses 501.8.3.1 and 501.8.3.2, the profile corrective course shall be laid using material as described in Clauses501.8.2.3 and 501.8.2.4, or as otherwise described in the Contract, and compacted to the requirements of the particular Specification.

501.8.3.4.2 Laying on existing bituminous surface : The existing bituminous surface shall be prepared in accordance with Clause 501.8.3.3, and after applying a tack coat conforming to Clause 503, the bituminous profile corrective course shall be laid and compacted to the requirements of the particular Specification.

501.8.3.4.3 Correction of local depressions : Where local sags or depressions occur in the existing pavement, a specific filling operation shall be instructed by the Engineer, which should be laid in accordance with Figure 500-1. Normally, the maximum layer thickness at any point should not exceed 100 mm. In placing multiple lifts, they should be arranged according to the correct method as illustrated.

For correction of camber or super-elevation of the existing carriageway, the method shown in Figure, 500-2 shall be adopted, depending on the profile of the existing carriageway.

501.8.3.5 Covering the profile corrective courses : Profile corrective course particularly shall be so planned that the layer shall be covered by the designed base/wearing course at the earliest opportunity, before opening to regular traffic.

501.8.4 Surface finish and quality control of work : The relevant provisions of Section 900 shall apply.

501.8.5 Arrangements for traffic : During construction operations, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

501.8.6 Environmental protection : The provisions of Clause 111 and the provision of Appendix A to Clause 501 shall apply.

501.8.7 Measurement for payment

501.8.7.1 Potholes and cracks : The work of filling potholes shall be measured separately and be paid for in square metres.

The work of filling cracks by applying fog spray or emulsion slurry seal shall be measured in square metres, for the area covered by the spray.

The work in filling cracks larger than 3 mm in width shall be measured and paid for on a linear metre basis.

501.8.7.2 Scarifying : Scarifying the existing bituminous surface shall be measured and paid for on a square metre basis.

501.8.7.3 Profile corrective course : Profile corrective course shall be measured as the volume instructed and compacted in position and measured in cubic metres, or in tonnage, as stipulated in the Contract. The volume shall be calculated by plotting the exact profile of profile corrective course as required, and laid, superimposed on the existing pavement profile. Cross-sectional areas of the profile corrective course shall be measured at intervals as used in the design, or as determined by the Engineer, and the volume shall be calculated using the method of end areas.

501.8.7.4 Prime coat : Prime coat shall be measured and paid for on a square metre basis.

501.8.7.5 Tack coat : This is to be a provisional item, which may be used in-part or not at all, at the Engineer's direction, and is to be measured and paid for, if used, on a square metre basis.

501.8.8 Rates

501.8.8.1 Rate for scarifying : The contract unit rate for scarifying existing bituminous surfaces, including repairing/reworking disturbed underlying layers and removing and stacking reusable/unusable materials, shall include for but not necessarily be limited to, the cost of all labour, supply of materials needed for repair/reworking, hire charges of tools and plant, and transportation of scarified materials.

501.8.8.2 Rate for premixed bituminous material : The contract unit rate for premixed bituminous material shall be payment in full for carrying out the required operations including full compensation for, but not necessarily limited to:

i) Making arrangements for traffic to Clause 112 except for initial treatment to verge, shoulders and construction of diversions.

ii) Preparation of the surface to receive the material.

iii) Providing all materials to be incorporated in the work including arrangement for stock yards, all royalties, fees, rents where necessary and all leads and lifts.

iv) Mixing, transporting, laying and compacting the mix, as specified.

v) All labour, tools, equipment, plant including installation of hot mix plant, power supply units and all machinery, incidental to complete the work to these Specification.

vi) Carrying out the work in part widths of the road where directed.

vii) Carrying out all tests for control of quality.

viii) The rate shall cover the provision of bitumen at the rate specified in the contract, with the provision that the variation in actual percentage of bitumen used will be assessed and the payment adjusted accordingly.

ix) The rates for premixed material are to include for all wastage in cutting of joints etc.

x) The rates are to include for all necessary testing, mix design, transporting and testing of samples, and cores. The Contractor shall arrange to carry out all necessary testing as directed by the Engineer,

and all costs incurred are deemed to be included in the Contractor's rates.

xi) The cost of all plant and laying trials as specified to prove the mixing and laying methods is deemed to be included in the Contractor's rates.

501.8.8.3 Rate for potholes and crack sealing : The rate for patching potholes shall include for breaking out, trimming edges, cleaning out, painting edges and bottom with bitumen, and filling and compacting the excavation with the specified material. The rate should be inclusive of all plant, tools, labour and materials, transport, and disposal of surplus material.

The contract unit rate for sealing cracks by applying fog spray shall be inclusive of providing all materials, tools, labour and plant and carrying out the work. The contract unit rate for sealing cracks by providing emulsion slurry seal shall be as set forth in Clause 513.9.

The contract unit rate for crack sealing 3mm to 6mm cracks with straight run or other specified bitumen, shall be based on either a square metre basis, or linear metre of cracks as measure, as stipulated by the Contract.

The contract unit rate for cracks between 6mm and 15mm is to be measured on a linear metre basis, and the rate is to include for all materials, tools, plant, labour, and transport.

Appendix 'A' to Clause 501

Appendix 'A'
PROTECTION OF THE ENVIRONMENT

1. General

1.1 This Appendix sets out limitations on the Contractor's activities specifically intended to protect the environment.

1.2 The Contractor shall take all necessary measures and precautions and otherwise ensure that the execution of the works and all associated operations on or off site are carried out in conformity with statutory and regulatory environmental requirements including those prescribed elsewhere in these Specifications.

1.3 The Contractor shall take all measures and precautions to avoid any nuisance or disturbance arising from the execution of the Works. This shall wherever possible be achieved by suppression of the nuisance at source rather than abatement of the nuisance once generated.

1.4 In the event of any spoil, debris, waste or any deleterious substance from the Site being deposited on any adjacent land, the Contractor shall immediately remove all such material and restore the affected area to its original state to the satisfaction of the Engineer.

2 Water Quality

2.1 The Contractor shall prevent any interference with the supply to or abstraction from, and prevent any pollution of, water resources (including underground percolating water) as a result of the execution of the Works.

2.2 Areas where water is regularly or repetitively used for dust suppression purposes shall be laid to fall to specially-constructed settlement tanks to permit sedimentation of particulate matter. After settlement, the water may be re-used for dust suppression and rinsing.

2.3 All water and other liquid waste products arising on the Site shall be collected and disposed of at a location on or off the Site and in a manner that shall not cause nuisance or pollution.

2.4 The Contractor shall not discharge or deposit any matter arising from the execution of the Works into any waters except with the permission of the Engineer and the regulatory authorities concerned.

2.5 The Contractor shall at all times ensure that all existing stream courses and drains within, and adjacent to, the Site are kept safe and free from any debris and any materials arising from the Works.

2.6 The Contractor shall protect all watercourses, waterways, ditches, canals, drains, lakes and the like from pollution as a result of the execution of the Works.

3 Air Quality

3.1 The Contractor shall devise and arrange methods of working to minimize dust, gaseous or other air-borne emissions and carry out the Works in such a manner as to minimize adverse impacts on air quality.

3.2 The Contractor shall utilize effective water sprays during delivery manufacture, processing and handling of materials when dust is likely to be created, and to dampen stored materials during dry and windy weather. Stockpiles of friable materials shall be covered with clean tarpaulins, with application of sprayed water during dry and windy weather. Stockpiles of material or debris shall be dampened prior to their movement, except where this is contrary to the Specifications.

3.3 Any vehicle with an open load-carrying area used for transporting potentially dust producing material shall have properly fitting side and tail boards. Materials having the potential to produce dust shall not be loaded to a level higher than the side and tail boards, and shall be covered with a clean tarpaulin in good condition. The tarpaulin shall be properly secured and extended at least 300 mm over the edges of the side and tail boards.

3.4 In the event that the Contractor is permitted to use gravel or earth roads for haulage, he shall provide suitable measures for dust palliation, if these are, in the opinion of the Engineer, necessary. Such measures may include sprinkling water on the road surface at regular intervals.

4 Noise

4.1 The Contractor shall consider noise abutment measures in his planning and execution of the Works.

4.2 The Contractor shall take all necessary measures so that the operation of all mechanical equipment and construction processes on and off the Site shall not cause any unnecessary or excessive noise, taking into account applicable environment requirements. The Contractor shall use all necessary measures and shall maintain all plant and silencing equipment in good condition so as to minimize the noise emission during construction works.

5 Control of Wastes

5.1 The Contractor shall control the disposal of all forms of waste generated by the construction operations and in all associated activities. No uncontrolled deposition or dumping shall be permitted. Wastes to be so controlled shall include, but shall not be limited to, all forms of fuel and engine oils, all types of bitumen, cement, surplus aggregates, gravels, bituminous mixtures etc. The Contractor shall make specific provision for the proper disposal of these and any other waste products, conforming to local regulations and acceptable to the Engineer.

6 Emergency Response

6.1 The Contractor shall plan and provide for remedial measures to be implemented in the event of occurrence of emergencies such as spillages of oil or bitumen or chemicals.

6.2 The Contractor shall provide the Engineer with a statement of the measures he intends to implement in the event of such an emergency, which shall include a statement of how he intends to provide personnel adequately trained to implement such measures.

7. Measurement

7.1 No separate measurement shall be made in respect of compliance by the Contractor with these provisions. The Contractor shall be deemed to have made allowance for such compliance with these provisions in the preparation of his prices for items of work included in the Bills of Quantities and full compensation for such compliance will be deemed to be covered by them.

502 PRIME COAT OVER GRANULAR BASE

502.1 Scope

This work shall consist of the application of a single coat of low viscosity liquid bituminous material to a porous granular surface preparatory to the superimposition of bituminous treatment or mix.

502.2 Materials

The bituminous material to be used as primer shall be such that it can penetrate about 10 mm deep into base course. Bitumen emulsion SS1 grade conforming to IS:8887/ASTM D2397 or medium curing cutback bitumen conforming to IS:2177 can be used as primer.

Quantity of SS1 grade bitumen emulsion for various types of granular surface shall be as per Table 500-1:

Table 500-1 Quantity of Bitumen Emulsion for Various Types of Granular Surface

Type of Surface	Rate of Spray (kg/sq.m)
WMM/WBM	0.7–1.0
Mechanically lime/cement stabilized soil bases, lime cement bases	0.9–1.2
Gravel bases, Crusher run Macadam and crushed rock bases	1.2–1.5

Cutback when used as primer shall not be prepared in field. Type and quantity of cutback bitumen for various types of granular surface shall be as per Table 500-2.

Table 500-2 Type and Quantity of Cutback Bitumen for Various Types of Granular Surface

Type of Surface	Type of Cutback	Rate of Spray (kg/sq.m)
WMM/WBM	MC 30	0.6–0.9
Mechanicallylime/cement stabilized soil bases, lime cement bases	MC 70	0.9–1.2
Gravel bases, Crusher run Macadam and crushed rock bases	MC 250	1.2–1.5

The correct quantity of primer shall be decided by the Engineer and shall be such that the maximum amount that can be absorbed by the surface without causing run-off of excessive primer and to achieve desired penetration of 10 mm**.**

502.3 Weather and Seasonal Limitations

Cutback bitumen as primer shall not be applied to a wet surface. Bitumen emulsion shall be applied on a damp surface. Surfaces which are to receive emulsion primer should be damp, but no free or standing water shall be present. Surface can be just wet by very light sprinkling of water. Primer shall not be applied during a dust storm or when the weather is foggy, rainy or windy or when the temperature in the shade is less than 10°C.

502.4 Construction

502.4.1 Equipment : The primer distributor shall be a self-propelled or towed bitumen pressure sprayer equipped for spraying the material uniformly at specified rates and temperatures. Hand spraying shall not be allowed except in small areas, inaccessible to the distributor, or in narrow strips where primer shall be sprayed with a pressure hand sprayer, or as directed by the Engineer.

502.4.2 Preparation of road surface : The surface to be primed shall be prepared in accordance with Clauses 501.8. and 902 as appropriate. Immediately prior to applying the primer, the surface shall be swept clean of dust and loose and other foreign particles using power broom or mechanical sweepers, care being taken not to disturb the interlocked aggregates.

502.4.3 Application of bituminous primer : After preparation of base as per 502.4.2, the primer shall be sprayed uniformly in accordance with Clause 501. The method for application of the primer will depend on the type of equipment to be used, size of nozzles, pressure at the spray bar and speed of forward movement. The Contractor shall demonstrate at a spraying trial, that the equipment and method to be used is capable of producing a uniform spray, within the tolerances specified.

No heating or dilution of SS1 emulsion and preparation of cutback bitumen shall be permitted at site. Temperature of cutback bitumen shall be high enough to permit the primer to be sprayed effectively.

502.4.4 Curing of primer and opening to traffic : A primed surface shall be allowed to cure for at least 24 hours or such other higher period as is found to be necessary to allow all the moisture/volatiles to evaporate before any subsequent surface treatment or mix is laid. Any unabsorbed primer shall first be blotted with an application of sand, using the minimum quantity possible. A primed surface shall not be opened to traffic other than that necessary to lay the next course.

502.4.5 Tack coat : Over the primed surface, a tack coat should be applied in accordance with Clause 503.

502.5 Quality Control of Work

For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

502.6 Arrangements for Traffic

During construction operations, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

502.7 Measurement for Payment

Prime coat shall be measured in terms of surface area of application in square metres.

502.8 Rate

The contract unit rate for prime coat shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 401.8 (i) to (v) and as applicable to the work specified in these Specifications. Payment shall be made on the basis of the provision of prime coat at an application rate of quantity, unless otherwise specified in the BOQ, at 0.6 kg per square metre, with adjustment, plus or minus, for the variation between this amount and the actual amount approved by the Engineer after the preliminary trials referred to in Clause 502.4.3.

503 TACK COAT

503.1 Scope

This work shall consist of the application of a single coat of low viscosity liquid bituminous material to an existing bituminous, cement concrete or primed granular surface preparatory to the superimposition of a bituminous mix, when specified in the Contract or instructed by the Engineer.

503.2 Materials

The binder used for tack coat shall be either Cationic bitumen emulsion (RS 1) complying with IS 8887/ASTM D 2397 or suitable low viscosity paving bitumen of VG 10 grade conforming to IS:73. The use of cutback bitumen RC:70 as per IS:217 shall be restricted only for sites at sub-zero temperatures or for emergency applications as directed by the Engineer. The type and grade of tack coat shall be as specified in the Contract or as directed by the Engineer.

503.3 Weather and Seasonal Limitations

Bituminous material shall not be applied during a dust storm or when the weather is foggy, rainy or windy or when the temperature in the shade is less than 10°C. Where the tack coat consists of emulsion, the surface shall be slightly damp, but not wet. Where the tack coat is of cutback bitumen, the surface shall be dry.

503.4 Construction

503.4.1 Equipment: The tack coat shall be applied by a self-propelled or towed bitumen pressure sprayer, equipped for spraying the material uniformly at a specified rate. Hand spraying shall not be permitted except in small areas, inaccessible to the distributor, or narrow strips, shall be sprayed with a pressure hand sprayer, or as directed by the Engineer.

503.4.2 Preparation of base: The surface on which the tack coat is to be applied shall be clean and free from dust, dirt, and any extraneous material, and be otherwise prepared in accordance with the requirements of Clauses 501.8 and 902 as appropriate. The granular or stabilized surfaces shall be primed as per Clause 502. Immediately before the application of the tack coat, the surface shall be swept clean with a mechanical broom, and high pressure air jet, or by other means as directed by the Engineer.

503.4.3 Application of tack coat : The application of tack coat shall be at the rate specified in the Contract, and shall be applied uniformly. If rate of application of Tack Coat is not specified in the contract, then it shall be the rate specified in Table 500-3. No dilution or heating at site of RS1 emulsion shall be permitted. Paving grade of bitumen if used for tack coat shall be heated in bitumen boilers to achieve viscosity less than 2 poise. The normal range of spraying temperature for a bituminous emulsion shall be 20°C to 70°C and for a cutback, 50°C to 80°C if RC-70/MC-70. Where a geosynthetic is proposed for use, the provisions of Clauses 703.3.2 and 703.4.4 shall apply. The method of application of tack coat will depend on the type of equipment to be used, size of nozzles, pressure at the spray bar, and speed or forward movement. The Contractor shall demonstrate at a spraying trial, that the equipment and method to be used is capable of producing a uniform spray, within the tolerances specified.

Where the material to receive an overlay is a freshly laid bituminous layer, that has not been subjected to traffic, or contaminated by dust, a tack coat is not mandatory where the overlay is completed within two days.

Table 500-3 Rate of Application of Tack Coat

Type of Surface	Rate of spray of emulsion /cutbackKg per sq m	Rate of spray of bitumen Kg per sq m
Bituminous surfaces	0.20 – 0.30	0.30 – 0.40
Granular surfaces treated with primer	0.25 – 0.30	0.35 – 0.45
Cement concrete pavement	0.30 – 0.35	0.40 – 0.50

503.4.4 Curing of tack coat

The tack coat shall be left to cure until all the volatiles have evaporated before any subsequent construction is started. No plant or vehicles shall be allowed on the tack coat other than those essential for the construction.

503.5 Quality Control of Work

For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

503.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

503.7 Measurement for Payment

Tack coat shall be measured in terms of surface area of application in square metres.

503.8 Rate

The contract unit rate for tack coat shall be payment in full for carrying out the required operations including for all components listed in Clause 401.8 (i) to (v) and as applicable to the work specified in these Specifications. The rate shall cover the provision of tack coat, quantity unless otherwise specified in the BOQ, at 0.2 kg per square metre, with the provision that the variance in actual quantity of bitumen used will be assessed and the payment adjusted accordingly.

504 LEAN BITUMINOUS MACADAM

504.1 Scope

This work shall consist of construction of 75 mm thick single course of compacted crushed aggregates premixed with a bituminous binder on a previously prepared base to the requirements of these Specifications. This specification may be used for laying of profile corrective course (PCC) where thickness of PCC is more than 75 mm and strengthening of weak bases, where strengthening by granular layer is not feasible due to difficulties in scarification or due to economical reasons.

504.2 Materials

504.2.1 Bitumen : Clause 506.2.1 shall apply

504.2.2 Coarse aggregate : Clause 506.2.2 shall apply

504.2.3 Fine aggregate : Clause 506.2.3 shall apply

504.2.4 Aggregate grading and binder content :

The combined grading of the coarse aggregates and fine aggregates, when tested in accordance with IS 2386 Part 1, wet sieving method, shall conform to limits given in Table 500-4. The quantity of bitumen and appropriate thickness is also given in Table 500-4.

Table 500-4 Aggregate Grading and Bitumen Content

Layer thickness	75 mm
IS Sieve size (mm)	Cumulative % by weight of total aggregate passing
45	100
26.5	75-100
22.4	60-95
11.2	30-55
5.6	15-35
2.36	4 – 19
0.075	0 – 5
Bitumen content ** percent by mass of total mix	2.5

* Nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate material is retained.

** Corresponds to specific gravity of the Aggregate being 2.7. In case of aggregates have specific gravity more than 2.7, bitumen content can be reduced proportionately.

504.2.5 The combined aggregate grading shall not vary from the lower limit on one sieve to the higher limit on the adjacent sieve to avoid gap grading. The aggregate may be proportioned and blended to produce a uniform mix complying with the requirements of Table 500-4.

504.2.6 **Proportioning of material :** The aggregates shall be proportioned and blended to produce a uniform mixture complying with the requirements of Table 500-4, The binder content shall be within a tolerance of $\pm$ 0.3 percent by weight of total mixture when individual specimens are taken for quality control tests in accordance with the provisions of Section 900.

504.3 Construction Operation

504.3.1 **Weather and seasonal limitations :** The provisions of Clause 501.5.1 shall apply.

504.3.2 **Preparation of the base :** The base on which bituminous macadam is to be laid shall be prepared, shaped and compacted to the required profile in accordance with Clauses 501.8 and 902.3 as appropriate, and a prime coat, shall be applied in accordance with Clause 502 where specified, or as directed by the Engineer.

504.3.3 **Tack coat :** A tack coat in accordance with Clause 503 shall be applied as required under the Contract, or as directed by the Engineer.

504.3.4 **Preparation and transportation of the mix :** The provisions of Clause 501.3 and 501.4 shall apply.

504.3.5 **Spreading :** The provisions of Clauses 501.5.3 shall apply.

504.3.6 **Rolling :** Compaction shall be carried out in accordance with the provisions of Clauses 501.6 and 501.7.

Rolling shall be continued until the specified density is achieved, or where no density is specified, until there is no further movement under the roller. The required frequency of testing is defined in Clause 903.

504.4 Surface Finish and Quality Control of Work

The surface finish of the completed construction shall conform to the requirements of Clause 902. For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

504.5 Protection of the Layer

The bituminous macadam shall be covered with either the next pavement course or wearing course, as the case may be, within a maximum of forty-eight hours. If there is to be any delay, the course shall be covered by a seal coat to the requirement of Clause 512 before opening to any traffic. The seal coat in such cases shall be considered incidental to the work and shall not be paid for separately.

504.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

504.7 Measurement for Payment

Bituminous macadam shall be measured as finished work in cubic metres, or by weight in metric tonnes, where used as regulating course, or square metres at the specified thickness as indicated in the Contract or shown on the drawings, or as otherwise directed by the Engineer.

504.8 Rate

The contract unit rate for bituminous macadam shall be payment in full for carrying out the required operations as specified. The rate shall include cost for, all components listed in Clause 501.8.8.2.

505 DENSE GRADED BITUMINOUS MACADAM

505.1 Scope

This clause specified the construction of Dense Bituminous Macadam, (DBM), for use mainly, but not exclusively, in base/binder and profile corrective courses. The work shall consist of construction in a single or multiple layers of DBM on a previously prepared base or sub-base. The thickness of a single layer shall be 50 mm to 100 mm.

505.2 Materials

505.2.1 Bitumen : The bitumen for dense bituminous macadam shall comply with the Indian Standard Specification for viscosity graded bitumen, IS:73 modified bitumen complying with IS:15462 or as otherwise specified in the Contract. Guidelines for selection of viscosity graded bitumen and modified bitumen are given in Table 500-5 and Table 500-6 respectively.

The type and grade of modified bitumen to be used shall be specified in the Contract. The use of modified bitumen is recommended for very heavy traffic roads in very hot climate.

Both the highest daily mean air temperature and the lowest daily mean air temperatures mentioned in Tables 500-5 and 500-6 can be obtained for the weather station nearest to the project site from the Indian Meteorological Organization (IMO). The IMO has data on daily mean high temperature for all 365 days in a year for all weather stations based on historical records of the last 30-40 or more years. This daily mean high temperature on a specific day is the same as daily "normal" high temperature for that day as usually reported in some newspapers. The highest of the 365 daily mean high air temperatures (which usually occurs on some day in May or June) is used in Tables 500-5 and 500-6. Likewise, the lowest daily mean air temperature (which usually occurs on some day in January) can also be obtained from the IMO. Since these are mean temperatures based on the average of 30-40 years data, these temperatures are significantly lower than the absolute maximum temperatures, which may have occurred in a specific year.

Table 500-5 Selection Criteria for Viscosity-graded (VG) Paving Bitumens Based on Climatic Conditions

	Highest Daily Mean Air Temperature, °C		
Lowest Daily Mean Air Temperature, °C	**Less than 20°C**	**20 to 30°C**	**More than 30°C**
More than –10°C	VG-10	VG-20	VG-30
-10°C or lower	VG-10	VG-10	VG-20

Table 500-6 Selection Criteria for Grade of Modified Bitumen

Lowest Daily Mean Air Temperature, °C	**Highest Daily Mean Air Temperature, °C**		
	Less than 20°C	**20 to 30°C**	**More than 30°C**
	Grade of Modified Bitumen		
More than -10°C	PMB/NRMB 120 CRMB 50	PMB/NRMB 70 CRMB 55	PMB/NRMB 40 CRMB 60
-10°C or lower	PMB/NRMB 40 CRMB 50	PMB/NRMB 120 CRMB 55	PMB/NRMB 70 CRMB 50

PMB = Polymer modified bitumen
NRMB= Natural rubber modified bitumen
CRMB= Crumb rubber modified bitumen

505.2.2 Coarse aggregates : The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve. They shall be clean,

hard, durable, of cubical shape, free from dust and soft or friable matter, organic or other deleterious substances. Where the Contractor's selected source of aggregates have poor affinity for bitumen, as a condition for the approval of that source, the bitumen shall be treated with an approved anti-stripping agent, as per the manufacturer's recommendations, without additional payment to the Contractor. Before approval of the source, the aggregates shall be tested for stripping. The aggregates shall satisfy the requirements specified in Table 500-7.

Where crushed gravel is proposed for use as aggregate, not less than 90 percent by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces.

Table 500-7 Physical Requirements for Coarse Aggregate for Dense Graded Bituminous Macadam

Property	**Test**		**Specification**
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS 2386 Part I
Particle shape	Flakiness Index longation Index	Max 15% Max 20%	IS 2386 Part I
Strength	Los Angeles Abrasion Value Aggregate Impact Value	Max 35% Max 27%	IS 2386 Part IV
Durability	Soundness either : Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS 2386 Part V
Water Absorption	Water Absorption	Max 2%	IS 2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate Mixtures	Minimum retained coating 95%	IS 6241
Water Sensitivity	Retained Tensile Strength*	Min 80%	ASHTO 283

* If the minimum retained tensile test strength falls below 80 percent, use of anti stripping agent is recommended to meet the requirement.

505.2.3 Fine aggregates : Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of the two, passing the 2.36 mm sieve and retained on the 75 micron sieve. Natural sand shall not be allowed in binder courses. However, natural sand upto 50 percent of the fine aggregate may be allowed in base courses. They shall be clean, hard, durable, dry and free from dust, and soft or friable matter, organic or other deleterious matter. The fine aggregate shall have a sand equivalent

value of not less than 50 when tested in accordance with the requirement of IS:2720 (Part 37). The plasticity index of the fraction passing the 0.425 mm sieve shall not exceed 4, when tested in accordance with IS: 2720 (Part 5).

505.2.4 Filter : Filter shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement approved by the Engineer. The use of hydrated lime should be encouraged because of its very good anti-stripping and antioxidant properties. The filler shall be graded within the limits indicated in Table 500-8.

Table 500-8 Grading Requirements for Mineral Filler

IS sieve (mm)	Cumulative per cent passing by weight of total aggregate
0.6	100
0.3	95 – 100
0.075	85 – 100

The filler shall be free from organic impurities and have a Plasticity Index not greater than 4. The Plasticity Index requirement shall not apply if filler is cement or lime. Where the aggregates fail to meet the requirements of the water sensitivity test in Table 500-7, then 2 per cent by total weight of aggregate, of hydrated lime shall be used and percentage of fine aggregate reduced accordingly.

505.2.5 Aggregate grading and binder content : When tested in accordance with IS:2386 Part 1 (wet sieving method), the combined grading of the coarse and fine aggregates and added filler for the particular mixture shall fall within the limits given in Table 500-9 for dense bituminous macadam grading 1 or 2 as specified in the Contract. To avoid gap grading, the combined aggregate gradation shall not vary from the lower limit on one sieve to higher limit on the adjacent sieve. The quantity of bitumen, and appropriate thickness, are also indicated for each mixture type.

505.3 Mix Design

Bitumen content indicated in the Table 500-9 is the minimum. The exact bitumen content required shall be determined following the Marshall mix design procedure contained in Asphalt Institute Manual MS–2.

The fines to bitumen F/B ratio by weight of total mix shall range from 0.6 to 1.2.

505.3.1 Requirements for the mix : Apart from conformity with the grading and quality requirements for individual ingredients, the mixture shall meet the requirements set out in Table 500-10.

Table 500-9 Composition of Dense Graded Bituminous Macadam Pavement Layers

Grading	1	2
Nominal aggregate size*	**37.5 mm**	**26.5 mm**
Layer thickness	**75 – 100 mm**	**50 – 75 mm**
IS Sieve[1] (mm)	**Cumulative % by weight of total aggregate passing**	
45	100	
37.5	95 – 100	100
26.5	63-93	90-100
19	-	71-95
13.2	55-75	56-80
9.5	-	-
4.75	38-54	38-54
2.36	28-42	38-54
1.18	-	-
0.6	-	-
0.3	7 – 21	7-21
0.15	-	-
0.075	2 – 8	7-21
Bitumen content % by mass of total mix **	Min 4.0	Min 4.5

Notes: * The nominal maximum particle size is the largest specified sieve size upon which any of the aggregate is retained.

** Corresponds to specific gravity of aggregates being 2.7. In case aggregate have specific gravity more than 2.7, the bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is – 10°C or lower, the bitumen content may be increased by 0.5 percent

Table 500-10 Requirements for Dense Graded Bituminous Macadam

Properties	Viscosity Graded Bitumen	Modified bitumen Hot climate	Modified bitumen Cold climate	Test Method
Compaction level	75 blows on each face of the specimen			
Minimum stability (kN at 60°C)	9.0	12.0	10.0	AASHTO T245
Marshall flow (mm)	2 – 4	2.5 – 4	3.5 – 5	AASHTO T245
Marshall Quotient	2 – 5	2.5 - 5		MS -2 and ASTM D2041
% air voids	3 – 5			
% voids filled with bitumen		65 – 75		
Coating of aggregate particle		95% minimum		IS 6241
Tensile Strength ratio		80% Minimum		AASHTO T 283
% voids in Mineral aggregate VMA	Minimum per cent voids in mineral aggregate (VMA) are set out in Table 500-11.			

Table 500-11 Minimum Per Cent Voids In Mineral Aggregate (Vma)

Nominal Maximum Particle Size[1] (mm)	Minimum VMA, Per cent Related to Design Air voids, Percent[2]		
	3.0	**4.0**	**5.0**
26.5	11.0	12.0	13.0
37.5	10.0	11.0	12.0

Notes: 1) The normal maximum particle size is one size larger than the first sieve to retain more than 10 percent.

2) Interpolate minimum voids in the mineral aggregate (VMA) for design air voids values between those listed.

505.3.2 Binder content : The binder content shall be optimized to achieve the requirements of the mix set out in Table 500-10. The Marshall method for determining the optimum binder content shall be adopted as described in the asphalt institute Manual MS-2.

Where maximum size of the aggregate is more than 26.5 mm, the modified Marshall method using 150 mm diameter specimen described in MS-2 and ASTM D 5581 shall be used. This method requires modified equipment and procedures. When the modified Marshall test is used, the specified minimum stability values in Table 500-10 shall be multiplied by 2.25, and the minimum flow shall be 3 mm.

505.3.3 Job mix formula : The Contractor shall submit to the Engineer for approval at least 20 days before the start the work, the job mix formula proposed for use in the works, together with the following details:

i) Source and location of all materials;

ii) Proportions of all materials expressed as follows where each is applicable:

a) Binder type, and percentage by weight of total mix;

b) Coarse aggregate/Fine aggregate/Mineral filler as percentage by weight of total aggregate including mineral filler;

iii) A single definite percentage passing each sieve for the mixed aggregate;

iv) The individual gradings of the individual aggregate fraction, and the proportion of each in the combined grading;

v) The results of mix design such as maximum specific gravity of loose mix (Gmm), compacted specimen densities, Marshall stability,flow, air voids, VMA, VFB and related graphs and test results of AASHTO T 283 Moisture susceptibility test;

vi) Where the mixer is a batch mixer, the individual weights of each type of aggregate, and binder per batch;

vii) Test results of physical characteristics of aggregates to be used;

viii) Mixing temperature and compacting temperature.

While establishing the job mix formula, the Contractor shall ensure that it is based on a correct and truly representative sample of the materials that will actually be used in the work and that the mixture and its different ingredients satisfy the physical and strength requirements of these Specifications.

Approval of the job mix formula shall be based on independent testing by the Engineer for which samples of all ingredients of the mix shall be furnished by the Contractor as required by the Engineer.

The approved job mix formula shall remain effective unless and until a revised Job Mix Formula is approved. Should a change in the source of materials be proposed, a new job mix formula shall be forwarded by the Contractor to the Engineer for approval before the placing of the material.

505.3.4 Plant trials – permissible variation in job mix formula : Once the laboratory job mix formula is approved, the Contractor shall carry out plant trials to establish that the plant can produce a uniform mix conforming to the approved job mix formula. The permissible variations of the individual percentages of the various ingredients in the actual mix from the job mix formula to be used shall be within the limits as specified in Table 500-12 and shall remain within the gradation band. These variations are intended to apply to individual specimens taken for quality control tests in accordance with Section 900.

Table 500-12 Permissible Variations from the Job Mix Formula

Description	Base/binder Course
Aggregate passing 19 mm sieve or larger	+ 8%
Aggregate passing 13.2 mm, 9.5 mm	+ 7%
Aggregate passing 4.75 mm	+ 6%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	+ 5%
Aggregate passing 0.3 mm, 0.15 mm	+ 4%
Aggregate passing 0.075 mm	+ 2%
Binder content	+ 0.3%
Mixing temperature	+ 10°C

505.3.5 Laying trials : Once the plant trials have been successfully completed and approved, the Contractor shall carry out laying trials, to demonstrate that the proposed mix

can be successfully laid, and compacted all in accordance with Clause 501. The laying trial shall be carried out on a suitable area which is not to form part of the works, unless specifically approved in writing by the Engineer. The area of the laying trials shall be a minimum of 100 sq.m of construction similar to that of the project road, and it shall be in all respects, particularly compaction, the same as the project construction, on which the bituminous material is to be laid.

The Contractor shall previously inform the Engineer of the proposed method for laying and compacting the material. The plant trials shall then establish if the proposed laying plant, compaction plant, and methodology is capable of producing satisfactory results. The density of the finished paving layer shall be determined by taking cores, no sooner than 24 hours after laying, or by other approved method. The compacted layers of Dense Graded Bituminous Macadam (DBM) shall have a minimum field density equal to or more than 92% of the average theoretical maximum specific gravity (Gmm) obtained on the day of compaction in accordance with ASTM D2041

Once the laying trials have been approved, the same plant and methodology shall be applied to the laying of the material on the project, and no variation of either shall be acceptable, unless approved in writing by the Engineer, who may at his discretion require further laying trials.

505.4 Construction Operations

505.4.1 Weather and seasonal limitations : The provisions of Clause 501.5.1 shall apply.

505.4.2 Preparation of base : The base on which Dense Graded Bituminous Material is to be laid shall be prepared in accordance with Clause 501 and 902 as appropriate, or as directed by the Engineer. The surface shall be thoroughly swept clean by a mechanical broom, and the dust removed by compressed air. In locations where mechanical broom cannot get access, other approved methods shall be used as directed by the Engineer.

505.4.3 Geosynthetics : Where Geosynthetics are specified in the Contract, this shall be in accordance with the requirements stated in Clause 703.

505.4.4 Stress absorbing layer : Where a stress absorbing layer is specified in the Contract, this shall be applied in accordance with the requirements of Clause 517.

505.4.5 Prime coat : Where the material on which the dense bituminous macadam is to be laid is other than a bitumen bound layer, a prime coat shall be applied, as specified, in accordance with the provisions of Clause 502, or as directed by the Engineer.

505.4.6 Tack coat : Where the material on which the dense bituminous macadam is to be laid is either bitumen bound layer or primed granular layer, tack coat shall be applied, as specified, in accordance with the provisions of Clause 503, or as directed by the Engineer.

505.4.7 Mixing and transportation of the mix : The provisions as specified in Clauses 501.3 and 501.4 shall apply. Table 500-15 gives the mixing, laying and rolling temperature for dense mixes using viscosity graded bitumen. In case of modified bitumen, the temperature of mixing and compaction shall be higher than the mix with viscosity graded bitumen. The exact temperature depends upon the type and amount of modifier used and shall be adopted as per the recommendations of the manufacturer. In order to have uniform quality, the plant shall be calibrated from time to time.

505.4.8 Spreading : The provisions of Clauses 501.5.3 and 501.5.4 shall apply.

505.4.9 Rolling : The general provisions of Clauses 501.6 and 501.7 shall apply, as modified by the approved laying trials. The compaction process shall be carried out by the same plant, and using the same method, as approved in the laying trials, which may be varied only with the express approval of the Engineer in writing.

505.5 Opening to Traffic

It shall be ensured that the traffic is not allowed without the express approval of the Engineer in writing, on the surface until the paved mat has cooled below 60^{0}C in its entire depth.

505.6 Surface Finish and Quality Control of Work

The surface finish of the completed construction shall conform to the requirements of Clause 902. All materials and workmanship shall comply with the provisions set out in Section 900 of these Specifications.

505.7 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

505.8 Measurement for Payment

Dense Graded Bituminous Materials shall be measured as finished work either in cubic metres, tonnes or by the square metre at a specified thickness as detailed in the Contract drawings, or documents, or as otherwise directed by the Engineer.

505.9 Rate

The contract unit rate for Dense Graded Bituminous Macadam shall be payment in full for carrying out all the required operations as specified and shall include, but not necessarily

limited to all components listed in Clause 501.8.8.2. The rate shall include the provision of bitumen, at 4 percent and 4.5 percent by weight of the total mixture for grading 1 and grading 2 respectively.

The variation in actual percentage of bitumen used will be assessed and the payment adjusted plus or minus accordingly.

506 BITUMINOUS MACADAM

506.1 Scope

This work shall consist of construction in a single course having 50 mm to 100mm thickness or in multiple courses of compacted crushed aggregates premixed with a bituminous binder on a previously prepared base to the requirements of these Specifications. Bituminous macadam is more open graded than the dense graded bituminous materials described in Clauses 508 and 505. Since the bituminous macadam is an open-graded mixture, there is a potential that it may trap water or moisture vapour within the pavement system. Therefore, adjacent layer should have proper drainage quality to prevent moisture-induced damage to the BM.

506.2 Materials

505.2.1 Bitumen

The bitumen shall be viscosity graded paving bitumen complying with Indian Standard Specification for paving bitumen, IS:73. The grade of bitumen to be used would depend upon the climatic conditions and the traffic. Guidelines for selection of viscosity grade of paving grade bitumen are given in Table 500-5.

506.2.2 Coarse aggregates

The coarse aggregates shall consist of crushed rock, crushed gravel or other hard material retained on 2.36 mm sieve. It shall be clean, hard, durable and cubical shape, free from dust and soft organic and other deleterious substances. The aggregate shall satisfy the physical requirements specified in Table 500-13. Where crushed gravel is proposed for use as aggregate, not less than 90 percent by weight of the crushed material retained on 4.75 mm sieve shall have at least two fractured faces resulting from crushing operation. Before approval of the source, the aggregates shall be tested for stripping. Where the Contractor's selected source of aggregates have poor affinity for bitumen, as a condition

for the approval of that source, the bitumen shall be treated with approved anti-stripping agents, as per the manufacturer's recommendations, without additional payment.

Table 500-13 Physical Properties of Coarse Aggregate

Property	Test	Requirement	Test method
Cleanliness	Grain size analysis	Max. 5% passing 0.075 micron	IS 2386 Part I
Particle shape	Flakiness Index Elongation Index	Max. 16% Max 24%	IS 2386 Part I
Strength	Los Angeles Abrasion Value	Max. 40%	IS 2386 Part IV
	Aggregate Impact Value	Max. 30%	IS 2386 Part IV
Durability	Soundness (Sodium or Magnesium), 5 cycles		
	Sodium Sulphate	Max. 12%	IS 2386 Part V
	Magnesium Sulphate	Max. 18%	IS 2386 Part V
Water absorption	Water absorption	Max. 2%	IS 2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate	Min. Retained Coating 95%	IS 6241
Water sensitivity	Retained Tensile strength*	Min 80%	ASHTO 283

* If the minimum retained tensile strength falls below 80 percent, use of anti stripping agent is recommended to meet the minimum requirements.

506.2.3 Fine aggregates

Fine aggregates shall consist of crushed or naturally occurring mineral material, or a combination of two, passing 2.36 mm sieve and retained on 75-micron sieve. It shall be clean, hard, durable, free from dust and soft organic and other deleterious substances. The amount of rounded, natural sand in the total fine aggregate shall be limited to 10 percent if the BM is used within 100 mm from the road surface and to 50 percent if the BM is used more than 100 mm below the road surface.

506.2.4 Aggregate grading and binder content

The combined grading of the coarse aggregates and fine aggregates, when tested in accordance with IS:2386 Part 1, wet sieving method, shall conform to limits given in

Table 500-14. The type and quantity of bitumen and appropriate thickness is also given in Table 500-14.

Table 500-14 Aggregate Grading and Bitumen Content

Grading	**1**	**2**
Nominal maximum aggregate size*	40 mm	19 mm
Layer thickness	80 -100 mm	50 -75 mm
IS Sieve size (mm)	Cumulative % by weight of total aggregate passing	
45	100	
37.5	90-100	
26.5	75-100	100
19	-	90 – 100
13.2	35-61	56 – 88
4.75	13 – 22	16 – 36
2.36	4 – 19	4 – 19
0.3	2 – 10	2 – 10
0.075	0 – 8	0 – 8
Bitumen content ** percent by mass of total mix	3.3	3.4

* Nominal maximum aggregate size is the largest specified sieve size upon which any of the aggregate material is retained.

** Corresponds to specific gravity of the Aggregate being 2.7. In case aggregates have specific gravity more than 2.7, bitumen content can be reduced proportionately. Further, for regions where highest daily mean air temperature is 30°C or lower and lowest daily mean air temperature is –10°C or lower, the bitumen content may be increased by 0.5 percent.

506.2.5 The combined aggregate grading shall not vary from the lower limit on one sieve to the higher limit on the adjacent sieve to avoid gap grading. The aggregate may be proportioned and blended to produce a uniform mix complying with the requirements in Table 500-14.

506.2.6 Proportioning of material : The aggregates shall be proportioned and blended to produce a uniform mix complying with the requirements of Table 500-14. The binder content shall be within a tolerance of ± 0.3 percent by weight of total mixture when individual specimens are taken for quality control tests in accordance with the provisions of Section 900.

506.3 Construction Operation

506.3.1 Weather and seasonal limitations : The provisions of Clause 501.5.1 shall apply.

506.3.2 Preparation of the base : The base on which bituminous macadam is to be laid shall be prepared, shaped and compacted to the required profile in accordance with Clauses 501.8 and 902.3 as appropriate, and a prime coat, shall be applied in accordance with Clause 502 where specified, or as directed by the Engineer.

506.3.3 Tack coat : A tack coat in accordance with Clause 503 shall be applied as required under the Contract or as directed by the Engineer.

506.3.4 Preparation and transportation of the mix : The provisions of Clause 501.3 and 501.4 shall apply.

506.3.5 Spreading : The provisions of Clauses 501.5.3 shall apply.

Table 500-15 Mixing, Laying and Rolling Temparatures for Bituminous Mixes (Degree Celcius)

Bitumen Viscosity Grade	Bitumen Temperature	Aggregate Temperature	Mixed Material Temperature	Laying Temperature	*Rolling Temperature
VG-40	160-170	160-175	160-170	150 Min	100 Min
VG-30	150-165	150-170	150-165	140 Min	90 Min
VG-20	145-165	145-170	145-165	135 Min	85 Min
VG-10	140-160	140-165	140-160	130 Min	80 Min

* Rolling must be completed before the mat cools to these minimum temperatures.

506.3.6 Rolling : Compaction shall be carried out in accordance with the provisions of Clauses 501.6 and 501.7.

Rolling shall be continued until the specified density is achieved, or where no density is specified, until there is no further movement under the roller. The required frequency of testing is defined in Clause 903.

506.4 Surface Finish and Quality Control of Work

The surface finish of the completed construction shall conform to the requirements of Clause 902. For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

506.5 Protection of the Layer

The bituminous macadam shall be covered with either the next pavement course or wearing course, as the case may be, within a maximum of forty-eight hours. If there is to be any delay, the course shall be covered by a seal coat to the requirement of Clause 512 before opening to any traffic. The seal coat in such cases shall be considered incidental to the work and shall not be paid for separately.

506.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

506.7 Measurement for Payment

Bituminous macadam shall be measured as finished work in cubic metres, or by weight in metric tonnes, where used as regulating course, or square metres at the specified thickness as indicated in the Contract or shown on the drawings, or as otherwise directed by the Engineer.

506.8 Rate

The contract unit rate for bituminous macadam shall be payment in full for carrying out the required operations as specified. The rate shall include cost for all components listed in Clause 501.8.8.2.

507 SAND ASPHALT BASE COURSE

507.1 Scope

This work shall consist of a base course composed of a mixture of sand, mineral filler where required and bituminous binder, placed and compacted upon a prepared and accepted subgrade in accordance with these Specifications and the lines, levels, grades, dimensions and cross sections shown on the Drawings or as directed by the Engineer.

Note: Sand Asphalt Base course is used in special situations like quality coarse aggregates not being available within economical leads and/or water needed for conventional base course not being readily available, as in desert areas.

507.2 Materials

507.2.1 Bitumen : The bitumen shall be paving bitumen of viscosity grade VG 30 or VG 20, as specified in the Contract, conforming to IS:73.

507.2.2 Sand : The sand shall be clean, naturally occurring or blended material free from any deleterious substances, dry and well graded within the limits given in Table 500-16 and with other physical properties conforming to the requirements of this Table.

Table 500-16 Sand Grading and Physical Requirements

Sieve Size(mm)	Cumulative percentage by weight of total aggregate passing
9.5	100
4.75	85 – 100
2.36	80 – 100
1.18	70 – 98
0.60	55 – 95
0.30	30 – 75
0.15	10 – 40
0.075	4 – 10
Plasticity Index (%)	6 max.
Sand equivalent (IS:2720, Part 37)	30 min.
Los Angeles Abrasion Value (IS:2386, Part 4)	40 max.

Note: Maximum thickness for sand asphalt is 80 mm.

507.2.3 Filler : When required, filler shall consist of finely divided mineral matter such as rock dust, hydrated lime or cement as approved by the Engineer. The filler shall conform to Clause 505.2.4.

507.3 Mix Design

507.3.1 Requirements for the mixture : Apart from conformity with the grading and quality requirements for individual ingredients, the mixture shall meet the requirements set out in Table 500-17.

507.3.2 Binder content : The binder content shall be optimized to achieve the requirements of the mix set out in Table 500-17. The Marshall method for determining the optimum binder content shall be adopted as described in the Asphalt Institute Manual MS-2.

Table 500-17 Requirements for Sand Asphalt Base Course

Parameter	Requirement
Minimum stability (kN at 60°C)	2.0
Minimum flow (mm)	2
Compaction level (Number of blows)	2 x 75
Percent air voids	3–5
Percent voids in mineral aggregate (VMA)	16 min.
Percent voids filled with bitumen (VFB)	65-75

507.3.3 Job mix formula : The Contractor shall develop the job mix formula proposed for use in the works and submit it to the Engineer for approval together with the following details :

i) Source and location of all materials;

ii) Proportions of all materials expressed as follows where each is applicable:

a) Binder, as percentage by weight of total mixture;

b) Sand/Mineral filler as percentage by weight of total aggregate including mineral filler;

iii) A single definite percentage passing each sieve for the mixed aggregate;

iv) The results of tests enumerated in Table 500-17 as obtained by the Contractor;

v) Test results of physical characteristics of aggregates to be used;

vi) Mixing temperature and compacting temperature.

While working out the job mix formula, the Contractor shall ensure that it is based on a correct and truly representative sample of the materials that will actually be used in the work and that the mixture and its different ingredients satisfy the physical and strength requirements of these Specifications.

Approval of the job mix formula shall be based on independent testing by the Engineer for which joint samples of all ingredients of the mix shall be furnished by the Contractor as required by the former.

The approved job mix formula shall remain effective unless and until modified by the Engineer. Should a change in the source of materials be proposed, a new job mix formula shall be established by the Contractor and approved by the Engineer before actually using the materials.

507.3.4 Permissible variation from job mix formula : The Contractor shall produce a uniform mix conforming to the approved job mix formula, subject to the permissible variations of the individual percentages of the various ingredients in the actual mix from the job mix formula to be used, within the limits as specified in Table 500-12, with the condition that the gradation after the variation remains within the gradation envelop. These variations are intended to apply to individual specimens taken for quality control tests in accordance with Section 900.

507.4 Construction Operations

507.4.1 Weather and seasonal limitations : Clause 501.5.1 shall apply.

507.4.2 Preparation of base : The surface on which Sand Asphalt Basecourse Material is to be laid shall be prepared, shaped and graded in the profile required for the particular layer in accordance with Clause 501 and 902 as appropriate or as directed by the Engineer. The surface shall be thoroughly swept clean free from dust and foreign matter using a mechanical brush, and the dust blown off by compressed air. In confined locations where mechanical plant cannot get access, other methods shall be used as approved by the Engineer. A prime coat, where specified, shall be applied in accordance with Clause 502 or as directed by the Engineer.

507.4.3 Tack coat : A tack coat over the base shall be applied in accordance with Clause 503, or otherwise as directed by the Engineer.

507.4.4 Preparation and transportation of the mixture : The provisions of Clause 501.3 and 501.4 shall apply.

507.4.5 Spreading : The provisions of Clauses 501.5.2 to 501.5.4 shall apply. Mixing must be accomplished at the lowest temperatures and in the shortest time that will produce a mixture with complete coating of the aggregate and at a suitable temperature to ensure proper compaction. Guidance for mixing and compaction temperature for the particular bitumen may be taken from Table 500-15 and shall correspond to a viscosity of 2 Poise (0.2 Pa.s) and 3 poise (0.3 Pa.s) respectively, based on the original (unaged) bitumen properties.

507.4.6 Rolling : Clause 501.6 shall apply. Generally the initial or breakdown rolling shall be done with 8-10 tonne deadweight smooth-wheeled rollers. The intermediate rolling shall be done with 8–10 tonne deadweight or vibratory rollers or with a pneumatic tyred roller of 12-15 tonne weight having a tyre pressure of at least 5.6 kg/sq.cm. The finish rolling shall be done with 8–10 tonne deadweight smooth wheeled tandem rollers. The exact pattern of rolling shall be established at the laying trials.

507.5 Opening to Traffic

It shall be ensured that the traffic is not allowed without the express approval of the Engineer in writing, on the surface until the paved mat has cooled below 60^0C in its entire depth.

507.6 Surface Finish and Quality Control of Work

The surface finish of the completed construction shall conform to the requirements of Clause 902.

For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

507.7 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

507.8 Measurement for Payment

Sand Asphalt Base course materials shall be measured as finished work, for the area covered, in cubic metres, metric tonnes, or in square metres, at a specified thickness, as stated in the Contract.

The variation from the actual percentage of bitumen approved by the Engineer and used will be assessed and the rate adjusted, plus or minus, using the rate for bitumen in the Bill of Quantities.

508 BITUMINOUS CONCRETE

508.1 Scope

This work shall consist of construction of Bituminous Concrete, for use in wearing and profile corrective courses. This work shall consist of construction in a single layer of bituminous concrete on a previously prepared bituminous bound surface. A single layer shall be 25mm/40 mm/50 mm thick.

508.2 Materials

508.2.1 **Bitumen :** The bitumen shall conform to Clause 505.2.1.

508.2.2 **Coarse aggregates :** The coarse aggregates shall be generally as specified in Clause 505.2.2, except that the aggregates shall satisfy the physical requirements of

Table 500-18 and where crushed gravel is proposed for use as aggregate, not less than 95 percent by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces.

.Table 500-18 Physical Requirements for Coarse Aggregate for Bituminous Concrete

Property	Test		Specification
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part I
Particle shape	Flakiness Index Elongetion index	Max 15% Max 20%	IS:2386 Part I
Strength	Los Angeles Abrasion Value Aggregate Impact Value	Max 30% Max 24%	IS:2386 Part IV
Durability	Soundness either : Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part V
Polishing	Polished stone value	Min 55	IS:2386 Part IV
Water Absorption	Water Absorption	Max 2%	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%	IS:6241
Water Sensitivity	Retained Tensile Strength*	Min 80%	AASHTO 283

* If the minimum retained tensile test strength falls below 80 percent, use of anti stripping agent is recommended to meet the requirement.

508.2.3 Fine aggregates: The fine aggregates shall be all as specified in Clause 505.2.3.

508.2.4 Filler: Filler shall be as specified in Clause 505.2.4.

508.2.5 Aggregate grading and binder content: When tested in accordance with IS:2386 Part 1 (Wet grading method), the combined grading of the coarse and fine aggregates and added filler shall fall within the limits shown in Table 500-19 for grading 1 or 2, as specified in the Contract.

Table 500-19 Composition of Bituminous Concrete Pavement Layers

Grading	1	2
Nominal aggregate size*	**19mm**	**13.2mm**
Layer thickness	**50 mm**	**25/40 mm**
IS Sieve[1] (mm)	**Cumulative % by weight of total aggregate passing**	
45		
37.5		
26.5	100	
19	79-100	100
13.2	59-79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content % by mass of total mix	5.2	5.4

Notes: * The nominal maximum particle size is the largest specified sieve size up on which any of the aggregate is retained.

** Corresponds to specific gravity of aggregate being 2.7. In case aggregate have specific gravity more than 2.7, the bitumen content can be reduced proportionately. Further the region where highest daily mean air temperature is 30°C or lower and lowest daily air temperature is – 10°C or lower, the bitumen content may be increased by 0.5 percent

508.3 Mix Design

508.3.1 Requirements for the mix: Clause 505.3.1 shall apply.

508.3.2 Binder content : Clause 505.3.2 shall apply.

508.3.3 Job mix formula: Clause 505.3.3 shall apply.

508.3.4 Plant trials – permissible variation in job mix formula: The requirements for plant trials shall be as specified in Clause 505.3.4, and permissible limits for variation as given in Table 500-20.

Table 500-20 Permissible Variations from the Job Mix Formula

Description	Bituminous concrete
Aggregate passing 19 mm sieve or larger	+ 7%
Aggregate passing 13.2 mm, 9.5 mm	+ 6%
Aggregate passing 4.75 mm	+ 5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	+ 4%
Aggregate passing 0.3 mm, 0.15 mm	+ 3%
Aggregate passing 0.075 mm	+ 1.5%
Binder content	+ 0.3%
Mixing temperature	+ 10°C

508.3.5 Laying trials : The requirements for laying trials shall be as specified in Clause 505.3.5. The compacted layers of bituminous concrete (BC) shall have a minimum field density equal to or more than 92 percent of the average theoretical maximum specific gravity (Gmm) obtained on the day of compaction in accordance with ASTM D2041.

508.4 Construction Operations

508.4.1 Weather and seasonal limitations : The provisions of Clause 501.5.1 shall apply.

508.4.2 Preparation of base : The surface on which the bituminous concrete is to be laid shall be prepared in accordance with Clauses 501 and 902 as appropriate, or as directed by the Engineer. The surface shall be thoroughly swept clean by mechanical broom and dust removed by compressed air. In locations where a mechanical broom cannot get access, other approved methods shall be used as directed by the Engineer.

508.4.3 Geosynthetics: Where Geosynthetics are specified in the Contract, this shall be in accordance with the requirements stated in Clause 703.

508.4.4 Stress absorbing layer : Where a stress absorbing layer is specified in the Contract, this shall be applied in accordance with the requirements of Clause 517.

508.4.5 Tack coat : The provisions as specified in Clause 505.4.5 shall apply.

508.4.6 Mixing and transportation of the mix : The provisions as specified in Clauses 501.3, 501.4 and 505.4.7 shall apply.

508.4.7 Spreading : The general provisions of Clauses 501.6 and 501.7 shall apply, as modified by the approved laying trials.

508.4.8 Rolling : The general provisions of Clauses 501.6 and 501.7 shall apply, as modified by the approved laying trials.

508.5 Opening to Traffic : Provisions in Clause 505.5 shall apply.

508.6 Surface Finish and Quality Control

The surface finish of the completed construction shall conform to the requirements of Clause 902. All materials and workmanship shall comply with the provisions set out in Section 900 of these Specifications.

508.7 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

508.8 Measurement for Payment

The measurement shall be as specified in Clause 505.8.

508.9 Rate

The contract unit rate shall be all as specified in Clause 505.9, except that the rate shall include the provision of bitumen at 5.2 percent and 5.4 percent for grading 1 and grading 2, by weight of total mix respectively. The variation in actual percentage of bitumen used will be assessed and the payment adjusted plus and minus accordingly.

509 CLOSE-GRADED PREMIX SURFACING/MIXED SEAL SURFACING

509.1 Scope

509.1.1 This work shall consist of the preparation, laying and compaction of a close-graded premix surfacing material of 20 mm thickness composed of graded aggregates premixed with a bituminous binder on a previously prepared surface, in accordance with the requirements of these Specifications, to serve as a wearing course.

509.1.2 Close graded premix surfacing shall be of Type A or Type B as specified in the Contract documents. Type A grading is recommended for use in areas having rainfall more than 150 cm per year. In other areas Type B grading may be used.

509.2 Materials

509.2.1 Binder : The provisions of Clause 511.1.2.1 shall apply.

509.2.2 Coarse aggregates : The provisions of Clause 511.1.2.2 shall apply.

509.2.3 Fine aggregates : The fine aggregates shall consist of crushed rock quarry sands, natural gravel/sand or a mixture of both. These shall be clean, hard, durable, un-coated, mineral particles, dry; and free from injurious, soft or flaky particles and organic or deleterious substances.

509.2.4. Aggregate gradation : The coarse and fine aggregates shall be so graded or combined as to conform to one or the other gradings given in Table 500-21, as specified in the contract.

Table 500-21 Aggregate Gradation

IS Sieve Designation (mm)	Cumulative percent by weight of total aggregate passing	
	Type A	Type B
13.2 mm	-	100
11.2 mm	100	88 – 100
5.6 mm	52 – 88	31 – 52
2.8 mm	14 – 38	5 – 25
0.090 mm	0 – 5	0 -5

509.2.5 Proportioning of materials : The total quantity of aggregates used for Type A or B close-graded premix surfacing shall be 0.27 cubic metre per square metre area. The quantity of binder used for premixing in terms of straight-run bitumen shall be 22.0 kg and 19.0 kg per 10 square metre area for Type A and Type B surfacing respectively.

509.3 Construction Operations

The provisions of Clause 511.1.3.1 through 511.1.3.5 shall apply.

509.4 Opening to Traffic

Traffic may be allowed after completion of the final rolling when the mix has cooled down to the surrounding temperature. Excessive traffic speeds should not be permitted.

509.5 Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Clause 902. For control on the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

509.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be in accordance with the provisions of Clause 112.

509.7 Measurement for Payment

Close-graded premix surfacing, Type A or B shall be measured as finished work, for the area specified to be covered, in square metres at a specified thickness. The area will be the net area covered, and all allowances for wastage and cutting of joints shall be deemed to be included in the rate.

509.8 Rate

The contract unit rate for close-graded premix surfacing, Type A or B shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

510 SURFACE DRESSING

510.1 Scope

This work shall consist of the application of one coat or two coats of surface dressing, each coat consisting of a layer of bituminous binder sprayed on a previously prepared, base, followed by a cover of stone chips rolled in to form a wearing course to the requirements of these Specifications. Surface dressing with pre-coated chips is also covered under in this specification.

510.2 Materials

510.2.1 Binder : The binder shall either be bitumen conforming to IS 73 or cationic bitumen emulsion conforming to IS: 8887. Grade of bitumen shall depend upon the climatic condition. For selection of grade of bitumen guidance may be taken from Table 500-5. The emulsion if used as binder shall be Rapid setting and shall have bitumen content not less than 65 percent. The type of binder to be used will be stated in the Contract documents, or as directed by the Engineer.

510.2.2 Aggregates : The chips shall conform to the requirements of clause 504.2.2., except that their water absorption shall be restricted to a maximum of 1 percent and they shall have a Polished Stone value, as measured by the method given in BS:812 (Part 114), of not less than 60. The chips shall be single sized, clean, hard, durable, of cubical shape; and free from dust and soft or friable matter, organic or other deleterious matter. The size of the aggregate depends upon the type of surface on which it is laid and the traffic. Table 500-22 may be used as guidance.

The recommended gradation for various aggregate sizes are given in Table 500-23

Pre-coated chips : As an alternative to the use of an adhesion agent, the chips may be pre-coated before they are spread except when the sprayed binder film is a bitumen

emulsion. Pre-coating the chips may be carried out by mixing aggregates with 0.75 to 1.0 percent of bitumen by weight of chips in a suitable mixer, the chips being heated to 160°C and the bitumen to its application temperature. The pre-coated chips shall be allowed to cure for at least one week or until they become non sticky and can be spread easily.

Table 500-22 Recommended Nominal size of Aggregates (mm)

Type of Surface	Traffic intensity in terms of number of commercial vehicles (with unladen weight greater than 15 kN) per day in the lane under consideration				
	2000-4000	1000-2000	200-1000	20-200	< 20
Very hard	10	10	6	6	6
Hard	13	13	10	6	6
Normal	19	13	10	6	6
Soft		19	13	13	10
Very soft			19	13	10

Table 500-23 Grading Requirements for Aggregates Used for Surface Dressing

IS Sieve designation (mm)	Cumulative percent by weight of total aggregates passing for the following nominal sizes (mm)			
	19	13	10	6
26.5	100			
19.	85-100	100		
13	0-40	85-100	100	
9.5	0-7	0-40	85-100	100
6.3		0-7	0-35	85-100
4.75			0-10	
3.35				0-35
2.36	0-2	0-2	0-2	0-10
0.60				0-2
0.075	0-1.5	0-1.5	0-1.5	0-1.5
Minimum 65% by weight of aggregate	Passing 19 and retained on 13.2	Passing 13.2 and retained on 9.5	Passing 9.5 and retained on 6.3	Passing 6.3 and retained on 3.35

510.2.3 Rates of spread of binder and chips : The quantity of material required will depend upon the extent of embedment in to the surface and will be determined by the design. Guidance on the design of surface dressing and the rate of spread of aggregates and binder shall be as taken from Appendix to IRC 110. Approximate rate of application of aggregates, and binder under average conditions are given in Table 500-24

Table 500–24 Approximate Rate of Application of Binder and aggregates

Nominal Aggregate Size mm	Binder (Kg/m^2)			Aggregates Cum/m^2
	Uncoated Aggregates		Coated Aggregates	
	Bitumen	Emulsion	Bitumen	
19	1.2	1.8	1.0	0.014-0.015
13	1.0	1.5	0.8	0.009-0.011
10	0.9	1.3	0.7	0.007-0.009
6	0.75	1.1	0.6	0.003-0.005

Note: In case of two coat Surface Dressing using emulsion, emulsion quantity for each coat may be added and 40 to 45 percent is applied in the first coat and remaining in second coat. Bitumen for coated aggregates excludes quantity of bitumen required for coating.

510.3 Construction Operations

510.3.1 Weather and seasonal limitations : Clause 501.5.1 shall apply.

510.3.2 Preparation of base : The base on which the surface dressing is to be laid shall be prepared, shaped and conditioned to the specified lines, grade and cross section in accordance with Clause 501 or as directed by the Engineer. Prime coat, where needed, shall be provided as per Clause 502 or as directed by the Engineer. Where the existing surface shows signs of fatting up, the excess bitumen shall be removed by burning off, or manually, directed by the Engineer. The bituminous surface to be dressed shall be thoroughly cleaned either by using a mechanical broom and/or compressed air, or directed any other approved equipment/method as specified in the Contract or directed by the Engineer. The prepared surface shall be dust free, clean and dry, (except in the case of cationic emulsion where the surface shall be damp).

510.3.3 Application of binder : The equipment described in IRC:SP:34 with synchronized spraying and compaction may be preferred for better control and uniformity in construction. After preparation of base, binder heated to an appropriate temperature shall be sprayed uniformly using mechanical sprayers. During the operation the ratio between truck speed and pump revolution shall be maintained constant with the help of automatic control. When work resumes, the binder shall not be sprayed on the earlier completed surface. This can be done by covering the completed work with bitumen impregnated paper. Excessive deposit of bituminous material shall be immediately removed.

510.3.4 Application of stone chips : Immediately after application of the binder, clean, dry chips (in the case of emulsion binder the chippings may be damp) shall be spread uniformly on the surface so as to cover the surface completely with a single layer of chips.

510.3.5 Rolling : Rolling of the chips should preferably be carried out by a pneumatic tyred roller in accordance with Clause 501.6 and 501.7. Rolling shall commence at the edges and progress towards the centre except in super-elevated and uni-directional cambered portions where it shall proceed from the lower edge to the higher edge. Each pass of the roller shall uniformly overlap not less than one-third of the track made in the preceding pass. While rolling is in progress, additional chips shall be spread by hand in necessary quantities required to make up irregularities. Rolling shall continue until all aggregate particles are firmly embedded in the binder and present a uniform closed surface.

510.3.6 Application of second coat of surface dressing : Where surface dressing in two coats is specified, the second coat should not be applied until the first coat has been open to traffic for 2 weeks. The surface on which the second coat is laid must be clean and free of dust. The construction operations for the second coat shall be the same as described in Clauses 510.3.3 and 510.3.5.

510.4 Opening to Traffic

Traffic shall not be permitted to run on any newly surface dressed area until the following day. In special circumstances, however, the Engineer may allow the road to be opened to traffic immediately after rolling, but in such cases traffic speed shall be limited to 20 km per hour until the following day.

510.5 Surface Finish and Quality Control of Work

The surface finish of construction shall conform to the requirements of Clause 902.

For control on the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

510.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

510.7 Measurement for Payment

Each coat of surface dressing shall be measured as finished work for the area instructed to be covered, in square metres.

510.8 Rate

The Contract unit rate for surface dressing, based on the notional rates of spread for binder and each size of chippings given in Clause 510.2.3, which shall be adjusted, plus or minus,

for the difference between the notional rates of spread and the rates of spread determined based on desigm, and approved by the Engineer, multiplied by the rates entered in the Bill of Quantities for binder and each size of chipping. The adjusted rate shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.89.2.

511 OPEN-GRADED PREMIX SURFACING

511.1 Open-graded Premix Surfacing using viscosity graded Bitumen or Cutback.

511.1.1 Scope : This work shall consist of the preparation, laying and compaction of an open-graded premix surfacing material of 20 mm thickness composed of small-sized aggregate premixed with bituminous binder on a previously prepared base, in accordance with the requirements of these Specifications, to serve as a wearing course.

511.1.2 Materials

511.1.2.1 Binder : The binder shall be viscosity graded bitumen of a suitable grade as specified in the Contract, or as directed by the Engineer, and satisfying the requirements of IS: 73. For selection of grade of bitumen guidance may be taken from Table 500-5.

511.1.2.2 Aggregates : The aggregates shall conform to Clause 504.2.2 except that the water absorption shall be limited to a maximum of 1 percent. The Polished Stone Value, as measured by the test in IS:2386 Part IV, shall not be less than 55.

511.1.2.3 Proportioning of material : The materials shall be proportioned in accordance with Table 500-25.

511.1.3 Construction operations

511.1.3.1 Weather and seasonal limitations : Clause 501.5.1 shall apply.

511.1.3.2 Preparation of surface : The underlying surface on which the bituminous surfacing is to be laid shall be prepared, shaped and conditioned to the specified lines, grade and cross-section in accordance with Clause 501. A prime coat where needed shall be applied in accordance with Clause 502 as directed by the Engineer.

511.1.3.3 Tack coat : A tack coat complying with Clause 503, shall be applied over the base preparatory to laying of the surfacing.

511.1.3.4 Preparation of premix : Hot mix plant of appropriate capacity and type shall be used for the preparation of the mix material. The hot mix plant shall have separate dryer arrangement for heating aggregate.

Table 500-25 Quantities of Materials Required for 10m² of Road Surface for 20 mm Thick Open-Graded Premix Surfacing

	Materials	Quantity
	Aggregates	
a)	Nominal Stone size 13.2 mm (passing 22.4 mm sieve and retained on 11.2mm sieve)	0.18m³
b)	Nominal Stone size 11.2 mm (passing 13.2 mm sieve and retained on 5.6 mm sieve)	0.09 m³
	Total	0.27 m³
	Binder (quantities in terms of straight run bitumen)	
a)	For 0.18 m³ of 13.2mm nominal size stone of 52 kg bitumen per m³	9.5 kg
b)	For 0.09 m³of 11.2mm nominal size stone of 56 kg bitumen per m³	5.2 kg
	Total	14.6 kg

The temperature of the binder and aggregate at the time of mixing, laying and compaction shall be in conformity with the temperature given in Table 500-4. The difference in temperature between the binder and aggregate shall at no time exceed 14°C. Mixing shall be thorough to ensure that a homogeneous mixture is obtained in which all particles of the aggregates are coated uniformly.

The mix shall be immediately transported from the mixer to the point of use in suitable vehicles or hand barrows. The vehicles employed for transport shall be clean and the mix being transported covered in transit if so directed by the Engineer.

511.1.3.5 Spreading and rolling : The pre mixed material shall be spread by suitable means to the desired thickness, grades and crossfall (camber) making due allowance for any extra quantity required to fill up depressions, if any. The cross-fall should be checked by means of camber boards and irregularities levelled out. Excessive use of blades or rakes should be avoided. As soon as sufficient length of bituminous material has been laid, rolling shall commence with 8–10 tonne rollers, smooth wheel tandem type or other approved equipment. Rolling shall begin at the edge and progress towards the centre longitudinally, except that on superelevated and uni-directional cambered portions, it shall progress from the lower to upper edge parallel to the centre line of the pavement.

When the roller has passed over the whole area once, any high spots or depressions, which become apparent, shall be corrected by removing or adding premixed materials. Rolling shall then be continued until the entire surface has been rolled and all the roller marks eliminated. In each pass of the roller the preceding track shall be overlapped uniformly by at least 1/3 width. The roller wheels shall be kept damp to prevent the premix from adhering to the wheels. In no case shall fuel/lubricating oil be used for this purpose. Excess use of water for this purpose shall also be avoided.

Rollers shall not stand on newly laid material. Rolling operations shall be completed in every respect before the temperature of the mix falls below the rolling temperature indicated

in Table 500-15. Joints along and transverse to the surfacing laid and compacted earlier shall be cut vertically to their full depth so as to expose fresh surface which shall be painted with a thin coat of appropriate binder before the new mix is placed against it.

511.1.3.6 Seal coat : A seal coat conforming to Clause 512 of the type specified in the Contract shall be applied to the surface immediately after laying the surfacing.

511.1.4 Opening to traffic : No traffic shall be allowed on the road until the seal coat has been laid. After the seal coat is laid, the road may be opened to traffic according to Clause 512.4.

511.1.5 Surface finish and quality control of work : The surface finish of construction shall conform to the requirements of Clause 902. For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

511.1.6 Arrangements for traffic : During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

511.1.7 Measurement for payment : Open graded premix surfacing shall be measured as finished work, for the area instructed to be covered, in square metres. The area will be the net area covered, and all allowance for wastage and cutting of joints shall be deemed to be included in the rate.

511.1.8 Rate : The contract unit rate for open-graded premix surfacing shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

511.2 Open Graded Premix Surfacing Using Cationic bitumen emulsion

511.2.1 Scope : This work shall consist of the preparation, laying and compaction of an open graded premix surfacing of 20 mm thickness composed of small-sized aggregate premixed with a cationic bitumen emulsion on a previously prepared surface, in accordance with the requirements of these Specifications, to serve as a wearing course.

511.2.2 Materials

511.2.2.1 Binder : The binder for Premix wearing course shall be cationic bitumen emulsion of Medium Setting (MS) grade complying with IS. 8887 and having a bitumen content 65 per cent minimum by weight. For liquid seal coat RS grade of Cationic bitumen emulsion shall be used. Where expressly specified in the Contract, MS grade emulsion shall be used or otherwise directed by the Engineer. Slow setting (SS) grade Cationic bitumen Emulsion shall be used for premix seal coat.

511.2.2.2 Aggregate : The requirements of Clause 511.1.2.2, shall apply.

511.2.3 Proportioning of materials: The materials shall be proportioned as quantities given in Tables 500-26 and 500-27.

Table 500-26 Quantities of Aggregate for 10m² Area

(A)	**Premix Carpet**		
	(a)	Coarse aggregate nominal 13.2 mm size, passing IS: 22.4 mm sieve and retained on IS:11.2 mm sieve	0.18 m^3
	(b)	Coarse aggregate nominal 11.2 mm size; passing IS:13.2 mm sieve and retained on IS 5.6 mm sieve	0.09m^3
(B)	**For Seal Coat :** Refer to Clause 512.		

Table 500-27 Quantities of Emulsion Binder

	For 10 m^2 area
(A) For Premix Carpet:	20 to 23 kg
(B) For Seal Coat:	
(a) for liquid seal coat	12 to 14 kg
(b) for premix seal coat	10 to 12 kg

511.2.4 Construction operations

511.2.4.1 Weather and seasonal limitations : Clause 501.5.1 shall apply except that the minimum air temperature for laying shall be 10°C. Cationic bitumen emulsions shall not normally be stored below 0°C.

511.2.4.2 Preparation of surface : The underlying surface on which the premix surfacing is to be laid shall be prepared, in accordance with the requirements of Clause 504.3.2 for a newly primed surface, and in accordance with Clause 505.4.2 where an existing bituminous surface is to be overlaid.

511.2.4.3 Preparation of binder : Before opening, the cationic bitumen emulsion drums shall be rolled at a slow speed, to and fro at least 5 times, for a distance of about 10 metres, to distribute any storage sedimentation.

511.2.4.4 Tack coat : A tack coat complying with Clause 503, shall be applied over the surface preparatory to laying of the surfacing where specified in the Contract, or directed by the Engineer.

511.2.4.5 Preparation of premix : Premixing of cationic bitumen emulsion and aggregates can be carried out in a suitable mixer such as cold mixing plant as per

IS: 5435 (Revised) or concrete mixer or by pay loaders in exceptional cases where approved by the Engineer. Where specified in the Contract, continuous mixing operation shall be done either in batch or continuous hot mix plant suitable for emulsion mixes.

When using concrete mixer for preparing the premix, 0.135 cu.m (0.09 cu.m of 13.2 mm size and 0.045 cu.m of 11.2 mm size) of aggregates per batch shall be used which quantity will be for 5 sq.m of road surface with 20 mm average thickness.

The aggregates required for one batch shall be prepared adjacent to the mixer.

First, the coarse aggregate of 13.2 mm size shall be placed into the mixer followed by 5 to 6.5 kg of Cationic bitumen emulsion and then the 11.2 mm size aggregate shall be added, followed by 5 to 6.5 kg of Cationic bitumen emulsion. After the materials have been mixed thoroughly, the mix shall be immediately transported to the laying site in suitable vehicles. Too much mixing shall be avoided.

When mixed manually by shovels, with the approval of the Engineer, 0.06 cu.m of aggregates can be conveniently mixed in one heap, with appropriate quantity of emulsion. It is preferable to make the aggregates damp before mixing as it reduces the effort required for mixing and also helps in getting better coating of aggregates. The 13.2 mm size aggregates and emulsion are mixed first and then the 11.2 mm size aggregates and remaining quantity of emulsion are added and mixed. Too much mixing shall be avoided.

511.2.4.6 Spreading and rolling : The premixed cationic bitumen emulsion and aggregates shall be spread within 10 minutes of applying the tack coat. All levelling, raking etc. should be completed within 20 minutes of the time of mixing.

The mix should be spread uniformly to the desired thickness, grades and crossfall (camber) making due allowance for any extra quantity required to fill up depressions, if any. The crossfall should be checked by means of camber boards and irregularities leveled out. Too much raking is to be avoided.

The rolling shall start immediately after laying the premix. A smooth wheeled tandem roller of 8-10 tonnes shall be used, unless other compaction methods are approved by the Engineer, based on the results of laying trials, if necessary. While rolling, wheels of roller should be clean and kept moist to prevent the premix from adhering to the wheels. In no case shall fuel/lubricating oil be used for this purpose. Use of water for this purpose shall be strictly limited to an absolute minimum.

Rolling shall commence at the edges and progress towards the centre longitudinally except in the case of superelevated and uni-directional cambered sections where rolling shall be carried out from the lower edge towards the higher edge parallel to the centre line of the road.

After one pass of roller over the whole area, depressions or uncovered spots should be corrected by adding premix material. Rolling shall be continued until the entire surface has been roller, to maximum compaction and all the roller marks eliminated. In each pass of the roller, the preceding track shall be overlapped uniformly by at least 1/3 width. Roller(s) shall not stand on newly laid material. Joints both longitudinal and transverse to the road sections laid and compacted earlier, shall be cut vertically to their full depth so as to expose fresh surface which shall be painted with a thin surface coat of binder before the new mix is placed against it.

511.2.4.7 Seal coat : A seal coat, conforming to Clause 512, as specified in the Contract, shall be applied immediately after laying the premix carpet.

511.2.5 Opening to traffic : Traffic should not be allowed over the premix surface till seal coat is laid. After the seal coat is laid, traffic may be allowed in accordance with Clause 512.4

511.2.6 Surface finish and quality control : The surface finish of construction shall conform to the requirements of Clause 902. For control of the quality of materials and work carried out, relevant provision of Section 900 shall apply.

511.2.7 Arrangements for traffic : During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

511.2.8 Measurement for payment : Open graded premix carpet shall be measured as finished work, for the area specified to be covered, in square metres at the specified thickness, in cubic metres, or in tonnes weight as specified in the Contract. The area will be the net area covered, and all allowances for wastage and cutting of joints shall be deemed to be included in the rate.

511.2.9 Rate : The contract unit rate for premix carpet and seal coat shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

512 SEAL COAT

512.1 Scope

512.1.1 This work shall consist of the application of a seal coat for sealing the voids in a bituminous surface laid to the specified levels, grade and cross fall (camber).

512.1.2 Seal coat shall be of either of the two types specified below:

A) Liquid seal coat comprising of an application of a layer of bituminous binder followed by a cover of stone chips.

B) Premixed seal coat comprising of a thin application of fine aggregate premixed with bituminous binder.

512.2 Materials

512.2.1 Binder : The requirements of Clauses 511.1.2.1 and 511.2.2.1 shall apply.

The quantity of bitumen per 10 square metres, shall be 9.8 kg for Type A, and 6.8 kg for Type B seal coat. Where bituminous emulsion is used as a binder, the quantities for Type A and Type B seal coats shall be 15 Kg and 10.5 Kg respectively.

512.2.2 Stone chips for Type A seal coat : The stone chips shall consist of angular fragments of clean, hard, tough and durable rock of uniform quality throughout. They should be free of soft or disintegrated stone, organic or other deleterious matter. Stone chips shall be of 6.7 mm size defined as 100 per cent passing through 11.2 mm sieve and retained on 2.36 mm sieve. The quantity used for spreading shall be 0.09 cubic metre per 10 square metre area. The chips shall satisfy the quality requirements given in Table 500-13 except that the upper limit for water absorption value shall be 1 percent.

512.2.3 Aggregate for Type B seal coat : The aggregate shall be sand or grit and shall consist of clean, hard, durable, uncoated dry particles, and shall be free from dust, soft or flaky/elongated material, organic matter or other deleterious substances. The aggregate shall pass 2.36 mm sieve and be retained on 180 micron sieve. The quantity used for premixing shall be 0.06 cubic metre per 10 square metre area.

512.3 Construction Operations

512.3.1 Weather and seasonal limitations: The requirements of Clause 501.5.1 shall apply.

512.3.2 Preparation of surface: The seal coat shall be applied immediately after laying the bituminous course which is required to be sealed. Before application of seal coat materials, the surface shall be cleaned free of any dust or other extraneous matter.

512.3.3 Construction of Type A seal coat: Bitumen shall be heated to temperature as per Table 500-15. and sprayed at the rate specified on the dry surface in a uniform manner with a self-propelled mechanical sprayer as described in the Manual for Construction and Supervision of Bituminous Works.

Immediately after the application of binder, stone chips, which shall be clean and dry, shall be spread uniformly at the rate specified on the surface preferably by means of a self-propelled or towed mechanical grit spreader so as to cover the surface completely. If necessary, the surface shall be brushed to ensure uniform spread of chips.

Immediately after the application of the cover material, the entire surface shall be rolled with a 8-10 tonne smooth wheeled steel roller, 8-10 tonne static weight vibratory roller, or

other equipment approved by the Engineer after laying trials if required. Rolling shall commence at the edges and progress towards the centre except in superelevated and uni-directional cambered portions where it shall proceed from the lower edge to the higher edge. Each pass of the roller shall uniformly overlap not less than one-third of the track made in the preceding pass. While rolling is in progress, additional chips shall be spread by hand in necessary quantities required to make up irregularities. Rolling shall continue until all aggregate particles are firmly embedded in the binder and present a uniform closed surface.

512.3.4 Construction Type B seal coat : A mixer of appropriate capacity and type approved by the Engineer shall be used for preparation of the mixed material. The plant shall have separate dryer arrangements for heating aggregate.

The binder shall be heated in boilers of suitable design, approved by the Engineer to the temperature appropriate to the grade of bitumen as per Table 500-15 or as directed the Engineer. The aggregates shall be dry and suitably heated to a temperature as per Table 500-15 or as directed by the Engineer before these components are placed in the mixer. Mixing of binder with aggregates to the specified proportions shall be continued until the latter are thoroughly coated with the former.

The mix shall be immediately transported from the mixing plant to the point of use and spread uniformly on the bituminous surface to be sealed.

As soon as a sufficient length has been covered with the premixed material, the surface shall be rolled with an 8-10 tonne smooth-wheeled roller. Rolling shall be continued until the premixed material completely seals the voids in the bituminous course and a smooth uniform surface is obtained.

512.4 Opening to Traffic

In the case of Type B seal coat, traffic may be allowed soon after final rolling when the premixed material has cooled down to the surrounding temperature. In the case of Type A seal coat, traffic shall not be permitted to run on any newly sealed area until the following day. In special circumstances, however, the Engineer may open the road to traffic immediately after rolling, but in such cases traffic shall be rigorously limited to 20 km per hour until the following day.

512.5 Surface Finish and Quality Control Work

The surface of construction shall conform to the requirements of Clause 902.

For control on the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

512.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

512.7 Measurement for Payment

Seal coat, Type A or B shall be measured as finished work, over the area specified to be covered, in square metres at the thickness specified in the Contract.

512.8 Rate

The contract unit rate for seal coat Type A or B shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

513 SLURY SEAL

513.1 Scope

Slurry seals are mixtures of fine aggregate, additives, slow setting cationic bitumen emulsion and additional water. Different types of slurry seal and their application is given in Table 500-28. This treatment shall be used for preventive maintenance and renewal treatment as substitute to surface dressing, premix carpet or mix seal surfacing for low traffic roads.

Table 500-28 Different Types of Slurry Seals

Items	Type I (2 – 3mm)	Type II (4 – 6 mm)	Type III (6-8 mm)**
Application	Filling of hair cracks	Filling of surface cracks 1- 3 mm and preventive/renewal treatment (upto 450 CVPD)	Filling of surface cracks 3- 6 mm and preventive/ renewal treatment (upto 1500 CVPD)
Quantity* of slurry (Kg /sq m)	4.3 to 6.5	8.4 to 9.8	10.1 to 12
Residual binder (% by weight of dry aggregate)	10 to 16	7.5 to 13.5	6.5 to 12

* In terms by weight of dry aggregate
** Indicative only

513.2 Materials

The materials for slurry seal immediately prior to mixing shall conform to the following requirements.

513.2.1 Emulsified bitumen : The emulsified bitumen shall be a cationic slow setting type SS 2 as approved by the Engineer, conforming to the requirements of IS:8887.

513.2.2 Aggregates : The mineral aggregates shall be crushed stone dust, clean, sharp, hard, durable, uncoated dry particle free from soft pieces and organic and other deleterious substances. The aggregate shall satisfy the requirement given in Table 500-29. The target grading shall conform to one of the three types given in Table 500-30. The aggregates shall meet the requirements of the film stripping test (IS:6241), and a suitable amount and type of anti-stripping agent added, as may be needed.

Table 500-29 Properties of Aggregates

Properties	Test Method	Specification
Sand equivalent	IS 2720 (Part 37)	Min 50 percent
Water absorption	IS 2386 (Part 3)	Max 2 percent
Soundness with; Sodium sulphate	IS 2386 (Part 5)	Max 12 percent
Magnesium sulphate		Max 18 percent

Table 500-30 Aggregate Grading, Binder Content And Approximate Coverage Rate

Sieve Size (mm)	Percentage by mass passing Finished thickness of sealing		
	Type I	Type II	Type III
9.5	---	--	100
6.3	---	100	90–100
4.75	100	90–100	70–90
2.36	90–100	65–90	45–70
1.18	65–90	45–70	28–50
0.600	40–65	30–50	19–34
0.300	25–42	18–30	12–25
0.150	15–30	10–21	7-18
0.075	10–20	5–15	5–15

513.2.3 Filler : Mineral filler shall be ordinary portland cement. The quantity of filler shall be preferably in the range of 0.5 percent to 2 percent by weight of dry aggregate.

513.2.4 Water : Water shall be of potable, free from harmful salt and contaminants. The pH of the water must lie in the range of 6 to 7.

513.2.5 Additives : Chemical additives may be used to accelerate or retard the break-set time of the slurry or to improve the resulting surface finish. The quantity of additive, if used, shall be decided by mix design and to be adjusted as per the site/climate conditions. The specifications for additive shall be supplied by the supplier of the emulsion. The additive and emulsion shall be compatible with each other.

513.3 Mix Design

The compatibility of aggregate, emulsion, filler and additive(if needed) shall be verified by mix design for a selected type and grading of aggregate as specified in Tables 500-29 and 500-30. The design criteria for slurry seal mixture is specified in Table 500-31 The proposed slurry seal mix shall conform to the specified requirements, when tested in accordance with tests specified in IRC SP 81. The mix design report shall clearly show the proportions of aggregate, filler, water and residual bitumen content based on the dry weight of the aggregates, additive usage (if any).

Table 500-31 Mix Design Criteria for Slurry Seal Mix

Requirement	Specifications	Test Method
Mix Time, minimum	180 seconds	Appendix 1 IRC:SP:81
Consistency, maximum	3 cm	Appendix 3 IRC:SP:81
Wet cohesion, pass % minimum	20 kg.cm	Appendix 4 IRC:SP:81
Wet striping, Pass %, minimum	90	Appendix 5 IRC:SP:81
Wet Track abrasion loss, (one hour soak), maximum	800 g/m^2	Appendix 6 IRC:SP:81

Aggregate, bitumen emulsion, water and additive including set control additive (if needed), shall be proportioned by weight utilizing the mix design approved by the Engineer. The final mixture, after addition of water and additive (if used) shall be such that the slurry seal mixture has proper workability and permit traffic within four hours (without leading to raveling after placement). Trial mix shall be prepared and laid at site for the designed mix and observed for breaking and setting time. Indicative limits of various ingredients for job mix of slurry seal shall be as given in Table 500-32.

513.4 Construction

513.4.1 Weather and seasonal limitations : Laying of slurry seal shall not be undertaken, if either the pavement temperature or air temperature below 10^{o}C. However during a dry spell , slurry seal may be laid in rainy season also, even if the surface is wet but there is no stagnant water on the pavement surface,

Table 500-32 Indicative Quantity of Ingredients

Ingredients	Limits (Percent by weight of dry aggregates)
Cationic Bitumen Emulsion	10 to 16 for Type I 7.5 to 13.5 for Type II 6.5 to 12 for Type III
Water	6 to 12
Filler	1.0 to 2.0
Additive	0.5 to 2.0

Tolerances : Percent passing each sieve shall not vary by more than the tolerance limit indicated in Table 500-33 and shall remain within the gradation band.

Table 500-33 Tolerances for Slurry Seal

Description	Tolerance
Aggregate passing 4.75 mm	+ 5%
Aggregate passing 2.36 mm, 1.18 mm, 0.6 mm	+ 5%
Aggregate passing 0.3 mm	+ 4%
Aggregate passing 0.15 mm	+ 3%
Aggregate passing 0.075 mm	+ 2%

513.4.2 **Surface preparation** : The underlying surface on which the slurry seal is to be applied shall be cleaned of all loose material, mud spots, vegetation and extraneous matter and shall be prepared and shaped to the needed profile. It is essential to pre-treat cracks on the pavement surface with an appropriate crack sealing material prior to application of slurry seal, if it is used for renewal treatment. The surface should be swept clean by removing caked earth and other foreign matter with wire brushes, sweeping with mechanical brooms and finally dusting with air jet or other means approved by the Engineer

513.4.3 **Application of tack coat :** Tack coat is not required normally for flexible pavements, unless surface is extremely hungry and dry. In case, it is needed, Clause 503 shall apply.

513.4.4 **Machine** : The machine shall be specially designed and manufactured to lay slurry seal/micro surfacing. It shall be self propelled equipment, truck mounted, consisting of following sub-assemblies used to manufacture and simultaneously spread these mixes on the surface.

- Aggregate bin.
- Filler bin.

- Water and Emulsion Tanks.
- Additive Tanks.
- Aggregates and filler conveyors to supply the mixer box.
- Pump or compressed air system to supply the emulsion/water.
- Mixer Box.
- Spreader box to place the mixed slurry on the job.

513.4.5 Calibration of Machine : Slurry seal laying machine shall be calibrated for flow of all the constituents as per the job mix in presence of Engineer. No machine shall be allowed to work on the project until the calibration has been completed and accepted by the Engineer. 2 kg samples of slurry seal mix will be taken and verified for proportioning and mix consistency. The verification for application rate shall also be carried out in Presence of the Engineer. The procedure for calibration and verification is as given in appendix 7 of IRC:SP:81.

513.4.6 Application of Slurry seal : A calibrated slurry seal machine, as per requirements of job mix, shall be used to spread the material. The surface shall be pre-wetted by fogging ahead of the spreader box (if required under hot weather conditions). The rate of application shall be adjusted during the day to suit temperature, surface texture and humidity. The mixture shall be agitated and mixed uniformly in the spreader box by means of twin shafted paddles or spiral augurs fixed in spreader box. A front seal shall be provided to ensure no loss of the mixture at the road contact point. The rear seal shall act as final strike off and shall be adjustable. The spreader box and real strike off shall be so designed and operated that a uniform consistency is achieved to produce free flow of material to the rear strike off. A Secondary strike off shall have the same adjustment as the spreader box. The spreader box shall have the suitable means provided to side shift the box to compensate for variation in pavement geometry. Sufficient amount of material shall be carried in all parts of spreader box at all times so that a complete coverage is obtained. Overloading of the spreader box shall be avoided. No lumping, balling and unmixed aggregates shall be permitted. No streak, caused by oversized aggregates shall be left on the finished surface. Longitudinal joints shall correspond with the edges of existing traffic lanes. The other patterns of longitudinal joints may be permitted, if pattern will not adversely affect the quality of finished surface. In case streak is formed, it shall be corrected immediately by fresh material and with use of squeeze. Longitudinal joints, common to two traffic lanes shall be butt joints with overlap not to exceed an average of 60-100 mm The mixture shall be uniform and homogeneous after spreading on existing surfaces and shall not show separation of the emulsion and aggregates after setting.

513.4.7 Rate of Application : As per Table 500-28 (by weight of dry aggregates)

513.4.8 Rolling : Generally rolling is not required. Where rolling is felt necessary due to inadequate cohesion, a pneumatic tyred roller having individual wheel load between 0.75 to 1.5 tonne shall be used. Rolling shall commence as soon as the slurry has set.

513.5 Surface Finish Quality Control : The surface finish of construction shall conform to the requirements of Clause 902. For control of the quality of materials and work carried out, relevant provision of Section 900 shall apply.

513.6 Opening to Traffic

Surface shall be opened to traffic after slurry is in completely set condition. The maximum setting time shall be 4 hours. Speed of traffic shall be restricted to 20 km per hour for next 12 hours.

513.7 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

513.8 Measurement for Payment

Slurry seal shall be measured as finished work as specified, in square metres.

513.9 Rate

The contract unit rate for slurry seal shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

514 FOG SPRAY

514.1 Scope

Fog spray is a very light application of low viscosity bitumen emulsion for purposes of sealing cracks less than 3mm wide or incipient fretting or disintegration in an existing bituminous surfacing, and to help reduce loosening of chips by traffic on newly finished surface dressing.

514.2 Material

The bitumen emulsion shall be as specified in the Contract or as instructed by the Engineer. The emulsion shall be SS-1h* (SS-1 can be used if the former is not available) complying with the requirements of ASTM D-977, or;

CSS-1h* (CSS-1 can be used if the former is not available) complying with the requirements of ASTM D-2397.

Before use, these emulsions shall be diluted, 1 part emulsion to 1 part water. Alternatively, Class A1-40* or K1-40* emulsions complying with the requirements of BS434:Part 1:1984 may be used. These emulsions have a lower viscosity than the above ASTM grades, they are rapid setting and they do not require to be diluted. Because of their low viscosity they should be used as soon as possible after delivery. If this is not possible, the drums should be very thoroughly rolled before use.

514.3 Weather and Seasonal Limitations

Spraying shall not take place when the temperature is below 10°C, nor in windy or dusty conditions, nor when it is raining or the surface to be sprayed is wet (a damp surface is acceptable but refer to Clause 514.4.2.).

514.4 Construction Operations

514.4.1 Equipment : The fog spray shall be applied by means of a self-propelled or towed bitumen pressure sprayer complying with the requirements of the Manual for Construction and Supervision of Bituminous Works. The spray bar should be protected from gusts of wind by means of a hood.

514.4.2 Preparation of surface : The surface on which the fog spray is to be applied shall be thoroughly cleaned with compressed air, scrubbers etc. The cracks shall be cleaned with a pressure air jet to remove all dirt, dust etc.

514.4.3 Application : The fog seal shall be applied at a rate of 0.5-1.0 litres/m², using equipment such as pressure tank, flexible hose and spray bar or lance.

514.5 Blinding

If specified in the Contract or ordered by the Engineer, the fog spray shall be blinded with graded grit of 3mm size and under, coated with about 2 per cent of the emulsion by weight. The pre coated grit shall be allowed to be cured for at least one week or until they become non-sticky and can be spread easily.

514.6 Quality Control of Work

For control of quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

514.7 Arrangements for Traffic

During the spraying operations, arrangements for traffic shall be made in accordance with the provisions of Clause 112. The surface should not be opened to traffic for 24 hours

after spraying. If pick-up does occur a light blinding of crusher dust or sand should be applied.

514.8 Measurement of Payment

Fog spray and blinding (if used) shall be measured in terms of surface area of application, for the area covered, in square metres.

514.9 Rate

The contract unit rate for got spray and blinding (if used) shall be payment in full for carrying out the required operations including full compensation for all components

listed in Clause 501.8.8.2. (i) to (xi) as applicable to the work specified in these Specifications.

515 MICRO-SURFACING

515.1 Scope

The micro-surfacing shall consist of mixture of modified (polymer or rubber latex) bitumen emulsion, mineral aggregate, water and necessary additives (if needed), proportioned, mixed and uniformly spread over a properly prepared surface. The mix shall be quick setting system, to be able to accept traffic after a short period of time preferably within about two hours depending upon weather conditions. This may be used as surface sealing treatment to improve skid resistance, surface durability, seal fine and medium cracks. It is applied when structurally sound pavement surface shows signs of premature ageing, aggregate loss, cracking, high degree of polishing etc. Micro-surfacing is laid in a single layer or multiple layers and used as preventive and periodic renewal treatment for low and medium trafficked road. Different types of micro surfacing and their application have been given in Table 500-34

Table 500-34 Different Types of Micro-Surfacing

Items	**Type II (4 to 6 mm)****	**Type III (6 to 8 mm) ****
Application	**Preventive and renewal treatment for roads carrying <1500 CVPD**	**Preventive and renewal treatment for roads carrying 1500 to 4500 CVPD**
Quantity of mix* (kg / m^2)	8.4 to 10.8	11.1 to 16.3
Residual binder (percentage by weight of dry aggregate)	6.5 to 10.5	5.5 to 10.5

* By weight of dry aggregate. ** Indicative only.

Note: Type 1 (2 to 4 mm) is not suitable for micro-surfacing.

515.2 Materials

515.2.1 Binder

The bitumen emulsion shall be a modified polymer modified / latex modified conforming to requirements specified in Table 500-35. Blending with modifier shall be prior to or during the emulsification process.

Table 500-35 Requirement of Modified Bitumen Emulsion for Micro-Surfacing

Requirements	Specifi-cations	Method of test
Residue on 600 µm IS sieve (percent by mass), maximum	0.05	IS: 8887
Viscosity by Say bolt Furol Viscometer, at 25°C, in second	20-100	IS :8887
Coagulation of emulsion at low temperature	Nil	IS :8887
Storage stability after 24 h (168 h), % maximum	2(4)	IS :8887
Particle charge, + ve/-ve	+ ve	IS :8887
Tests on residue:		
a) Residue by evaporation, % minimum	60	IS :8887
b) Penetration at 25°C/100 g/5 s	40-100	IS :1203
c) Ductility at 27°C, cm, minimum	50	IS :1208
d) Softening point, in °C, minimum	57	IS :1205
e) Elastic recovery*, %, minimum	50	IS :15462
f) Solubility in tri-chloroethylene, % minimum	97	IS :1216

* In case, elastic recovery is tested for Torsional Elasticity Recovery as per Appendix-8 of IRC 81, the minimum value shall be 20%.

515.2.2 Aggregates: As per Clause 513.2.2 (Type II and Type III Grading, Table 500-30).

515.2.3 Filler : As per Clause 513.2.3.

515.2.4 Water : As per Clause 513.2.4.

515.2.5 Additives : As per Clause 513.2.5.

515.3 Design and proportioning of micro-surfacing mix.

515.3.1 The design criterion for micro-surfacing mixture is specified in Table 500-36. The mix design report shall clearly show the proportions of aggregate, filler,

water and residual bitumen content based on the dry weight of aggregates and additives used (if any). The set time shall be determined by the method given in Appendix-2 of IRC:81.

515.3.2 Aggregate, modified bitumen emulsion, water and additive (if used), shall be proportioned by weight of aggregate utilizing the mix design approved by the Engineer. If more than one type of aggregates is used, the correct amount of each type of aggregate used to produce the required grading shall be proportioned separately prior to adding other materials of the mixture, in a manner that will result in a uniform and homogenous blend. Final completed mixture, after addition of water and any additive, if used shall be such that the micro-surfacing mixture has proper workability and permit traffic within one hour depending upon the weather conditions without occurrence of ravelling and bleeding. Trial mixes shall be prepared and laid for the designed mix and observed for breaking time and setting time. The wet track abrasion test is used to determine the minimum residual bitumen content. Indicative limits of various ingredients for job mix of micro-surfacing shall be as given in Table 500-37.

Table 500-36 Mix Design Criteria for Micro-Surfacing Mix

Requirement	Specifications	Method of test
Mix time, minimum	120 s	Appendix-1
Consistency, maximum	3 cm	Appendix-3
Wet Cohesion, within 30 min, minimum.	12 kg cm	Appendix-4
Wet Cohesion, within 60 min, minimum	20 kg cm	Appendix-4
Wet stripping, pass %, minimum	90	Appendix-5
Wet track abrasion loss (one hour soak), maximum	538 g/m^2	Appendix-6

Table 500-37 Indicative Ingredients in Mix

Ingredients	Limits (percent weight of aggregate)
Residual bitumen	6.5 to 10.5 for type II and 5.5 to 10.5 for Type III
Mineral filler	0.5 to 3.0
Additive	As needed
Water	As needed

515.4 **Construction :** As per clause 513.4.

515.4.1 **Weather and seasonal limitations :** As per clause 513.4.1.

515.4.2 **Surface preparation :** As per clause 513.4.2.

515.4.3 Application of tack coat : As per clause 513.4.3.

515.4.4 Machine : As per clause 513.4.4.

515.4.5 Calibration of machine : As per clause 513.4.5.

515.4.6 Application of micro-surfacing : A calibrated micor-surfacing machine as per requirements of job mix shall spread the material. The surface shall be pre-wetted (if required under extreme hot weather conditions) by spraying water ahead of the spreader box. The rate of application of micro surfacing shall be agitated and spread uniformly in the spreader box by means of twin-shafted paddles or spiral fixed in spreader box. A front seal shall be provided to ensure no loss of the mixture at the road contact point. The rear seal shall act as final strike off and shall be adjustable. The spread box and rear strike off shall be so designed and operated that a uniform consistency is achieved to produce free flow of material to the rear strike off. A secondary strike off shall have the same adjustment as the spreader box. The spreader box shall have suitable means provided to side shift the box to compensate for variations in the pavement geometry. A sufficient amount of material shall be carried in all parts of the spreader box at all times so that a complete coverage is obtained. Overloading of the spreader box shall be avoided. No lumping, balling and unmixed aggregates shall be permitted. No streak, caused by oversized aggregates shall be left on the finished surface. Longitudinal joints shall correspond with the edges of existing traffic lanes. The other patterns of longitudinal joints may be permitted if pattern will not adversely affect the quality of finished surface. Longitudinal joints, common to two traffic lanes shall be butt joints with overlap not to exceed an average of 60-100 mm. The mixture shall be uniform and homogenous after spreading on existing surfacing and shall not show separation of the emulsion and aggregates after setting.

515.4.7 Rate of application : The micro-surfacing mixture shall be proper consistency at all times so as to provide the application rate required by the surface condition. The quantities of micro-surfacing mix (by weight of dry aggregate) to be used shall be as given in Table 500-34.

515.4.8 Rolling : As per Clause 513.4.8.

515.5 Quality Control and Surface Finish : The surface finish of construction shall conform to the requirements of Clause 902. For control of the quality of materials and work carried out, relevant provision of Section 900 shall apply.

515.6 Control of Traffic

Micro-surfacing mix requires about 2 hours to set. Traffic may be opened only after 2 hours at the speed of 20 km/h till 12 hours thereafter.

515.7 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

515.8 Measurement for Payment

Slurry seal shall be measured as finished work as specified, in square metres.

515.9 Rate

The contract unit rate for slurry seal shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

516 STONE MATRIX ASPHALT (SMA)

516.1 SCOPE

This work shall consist of construction in a single or multiple layer of fibre-stabilized SMA on a previously prepared bituminous bound surface. SMA is based on the concept of designing a coarse aggregate skeleton so that stone-on-stone contact is obtained, which provides a highly rut-resistant bituminous course for heavy traffic roads. The 13mm SMA in this Specification is intended for wearing course with nominal layer thickness of 40 to 50mm. The 19 mm SMA is intended for binder (or intermediate) course with nominal layer thickness of 45 to 75 mm.

516.2 MATERIALS

516.2.1 Bitumen : The bitumen for fibre-stabilized shall be viscosity grade VG-30 complying with Indian Standard Specification for paving bitumen IS:73 for Polymer Modified Bitumen (PMB) Grade 40 complying with IS:15462.

516.2.2 Coarse aggregates : The coarse aggregates shall consist of crushed rock retained on 2.36 mm sieve. It shall be clean, hard, durable of cubical shape and free from dust and soft organic and other deleterious substances. The aggregates shall satisfy the physical requirements given in Table 500-38.

516.2.3 Fine aggregates : Fine aggregates (passing 2.36 mm sieve and retained on 0.075 mm sieve) shall consist of 100 percent crushed, manufactured sand resulting from crushing operations. The fine aggregate shall be clean, hard, durable, of fairly cubical shape and free from soft pieces, organic or other deleterious substances. The Sand Equivalent Test (IS:2720, Part 37) value for the fine aggregate shall not be less than 50. The fine aggregate shall be non plastic.

516.2.4 Mineral filler : Mineral filler shall consist of finely divided mineral matter such as stone, dust and/or hydrated lime. Fly ash will not be permitted as a filler in SMA. The filler shall be graded within the limits indicated in Table 500-39.

Table 500-38 Physical Requirements for Coarse aggregates for Stone Matrix Asphalt

Property	Test	Method	Specification
Cleanliness	Grain Size Analysis	IS:2386 (P-1)	< 2% passing 0.075 mm sieve
Particle Shape	Flakiness index Elongation Index	IS:2386 (P-1)	<12%< 18%
Strength	Los Angeles Abrasion Value	IS:2386 (P-4)	< 25%
	Aggregate Impact Value	IS:2386 (P-4)	< 18%
Polishing*	Polished Stone Value	IS:2386 (P-114)	> 55%
Durability	Soundness (either Sodium or Magnesium) - 5 cycles		
	Sodium Sulphate	IS:2386 (P-5)	< 12%
	Magnesium Sulphate	IS:2386 (P-5)	< 18%
Water Absorption	Water Absorption	IS:2386 (P-3)	< 2%

* Polishing requirement does not apply when the coarse aggregate is used in the 19 mm SMA, which is used as an intermediate (binder) course.

Table 500-39 Grading Requirement of Mineral Filler

IS sieve (mm)	Cumulative % passing byweight of total aggregate
0.6	100
0.3	95-100
0.075	85-100

The filler shall be inert material free from organic impurities and shall have plasticity index not greater than 4. Plasticity Index requirement will not apply if filler is hydrated lime. Where the complete SMA mixture fails to satisfy the requirement of Moisture Susceptibility Test (AASHTO T 283), at least 2 percent by total weight of aggregate of hydrated lime shall be used and the percentage of fine aggregate reduced accordingly.

516.2.5 **Stabilizer additive**: Only pelletized cellulose fibres shall be utilized. The dosage rate for cellulose fibres is 0.3 percent minimum by weight (on loose fibre basis) of the total mix. The dosage rate shall be confirmed so that the bitumen draindown does not exceed 0.3 percent when the designed mix is tested in accordance with ASTM D 6390.

516.2.5.1 The cellulose fibres to be used in pellets shall meet the following requirements:

Maximum fibre length	-	8 mm
Ash content	-	maximum of 20 percent non volatile
Oil absorption	-	more than 4 times of the fibre weight
Moisture content	-	less than 5 percent by weight

516.2.5.2 When the contractor submits the proposed job-mix formula for SMA for approval, it shall include the fibre manufacturer's most recently dated actual test data showing the fibres meet the above requirements. The Contractor shall protect the cellulose from moisture and contamination prior to incorporating it into the SMA.

516.3 SMA MIX DESIGN

516.3.1 The combined grading of the coarse aggregate, fine aggregate and mineral filler (including hydrated lime if used) shall be within the limits shown in Table 500-40.

Table 500-40 Composition of Stone Matrix Asphalt

SMA Designation	**13 mm SMA**	**19 mm SMA**
Course where used	Wearing course	Binder (intermediate) course
Nominal aggregate size	13 mm	19 mm
Nominal layer thickness	40-50 mm	45-75 mm
IS sieve (mm)	Cumulative % by weight of total aggregate passing	Cumulative % by weight of total aggregate passing
26.5	-	100
19	100	90-100
13.2	90-100	45-70
9.5	50-75	25-60
4.75	20-28	20-28
2.36	16-24	16-24
1.18	13-21	13-21
0.600	12-18	12-18
0.300	10-20	10-20
0.075	8-12	8-12

516.3.2 The SMA mixture will be designed using AASHTO MP8 Standard Specification for Designing Stone Matrix Asphalt and AASHTO PP 41. Standard Practice for Designing Stone Matrix Asphalt. The SMA mixture shall be compacted with 50 blows

on each side using the Marshall procedure given in the Asphalt Institute MS-2 (Sixth edition). The designed mix shall meet the requirements given in Table 500-41.

Table 500-41 SMA Mix requirements

Mix design parameters	Requirement
Air void content, percent	4.0
Bitumen content, percent	5.8 min.
Celluloid fibres	0.3 percent minimum by weight of total mix
Voids in mineral aggregate (VMA), percent	17 min.
VCA mix, percent	Less than VCA (dry rodded)
Asphalt draindown, percent AASHTO T 305 (Annex C)	0.3 max.
Tensile Strength Ratio (TSR), per cent AASHTO T 283 (Annex D)	85 min.

516.4 SMA Production

516.4.1 Mixing : The SMA mix shall be prepared in a hot mix plant of adequate capacity and capable of yielding a mix of proper and uniform quality with thoroughly coated aggregate.

When viscosity graded VG-30 bitumen is used, the mix temperature shall range from 150^0C to 165^0C. In case of polymer modified bitumen, the temperature of mixing and compaction shall be higher than the mix with VG-30 bitumen as binder. The exact temperature depends upon the type and amount of polymer used and shall be adopted as per the recommendations of the manufacturer. In order to ensure uniform quality of mix, the plant shall be calibrated from time to time.

516.4.2 Handling mineral filler : Adequate dry storage will be provided for the mineral filler and provisions shall be made for proportioning the filler into the mixture uniformly and in the desired quantities. This is necessary because relatively large amounts of mineral filler are required in SMA mixes.

516.4.3 Fibre additive : For batch plant, the fibre will be added directly into the weigh hopper above the pugmill. Adequate dry mixing time is required to disperse the fiber uniformly throughout the hot aggregate. Dry mixing time will be increased by 5 to 10 seconds. Wet mixing time shall be increased by at least 5 seconds. For drum mix plant, a separate fibre feeding system shall be utilized that can accurately and uniformly introduce fibre into the drum at such a rate as not to limit the normal production of mix through the drum. At no time shall there be any evidence of fibre in the baghouse /wasted baghouse fines.

516.5 SMA Placement and Compaction

516.5.1 Preparation of existing bituminous surface : The existing bituminous surface shall be cleaned of all loose extraneous matter by means of mechanical broom and high-pressure air jet from compressor or any other approved equipment/method. Any potholes and/or cracks shall be repaired and sealed.

516.5.2 Tack Coat : Clause 503 shall apply**.**

516.5.3 Transportation : Clause 501.4 shall apply.

516.5. 4 Laying

516.5.4.1 Weather and seasonal limitations : Clause 501.5.1 shall apply.

516.5.4.2 Spreading : Clause 501.5.3 shall apply.

516.5.5 Compaction : Clause 501.6. shall apply.

The density of the finished paving layer shall be determined by taking 150 mm diameter cores. The density of finished paving layer shall not be less than 94 percent of the average (sample size N=2) theoretical maximum specific gravity of the loose mix (G_{mm}) obtained on that day in accordance with ASTM D2041. That is, no more than 6 percent air voids shall be allowed in the compacted SMA mat.

516.5.6 Joints : Clause 501.4 shall apply.

516.6 Quality control and surface finish: The surface finish of construction shall conform to the requirements of Clause 902. For control of the quality of materials supplied and work carried out, relevant portion of Section 900 shall apply.

516.7 Control of traffic :

It shall be ensured that traffic is not allowed on the SMA surface until the paved mat has cooled to ambient temperature in its entire depth. Micro-surfacing mix requires about 2 hours to set. Traffic may be opened only after 2 hours at the speed of 20 km / h till 12 hours thereafter.

516.8 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

516.9 Measurement for Payment

Slurry seal shall be measured as finished work as specified, in square metres.

516.10 Rate

The contract unit rate for slurry seal shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

517 CRACK PREVENTION COURSES

517.1 Scope

This clause covers the provisions of Stress Absorbing Membrane (SAM) and Stress Absorbing Membrane Interlayer (SAMI) as measures to inhibit the propagation of cracks. SAM is an elastomeric bitumen rubber membrane, which is laid over a cracked road surface, together with a covering of aggregate chips, in order to extend the life of the pavement before major treatment is carried out. SAM can be laid as a single coat or a double coat. SAMI is a layer which is applied to a cracked pavement surface but which is followed (within 12 months) by the application of an overlay course. SAMI may be a material similar to that used for a SAM. It may alternatively consist of a bitumen impregnated geotextile.

517.2 Materials

517.2.1 Binder : Binder shall be a modified binder complying with the requirements of IS:15462, according to the requirements of the Contract, except that viscosity grade VG 10 complying with the requirements of IS:73 shall be used in the case of a bitumen impregnated geotextile.

517.2.2 Aggregate : The requirements of Clause 510.2.2 apply except that the Polished Stone Value requirement does not apply in the case of SAMI. Where required by the contract, aggregate shall be pre-coated using either of the techniques permitted by Clause 510.2.5.

517.2.3 Rates of spread of binder and aggregate : The rate of spread of binder and aggregate shall be according to one of the size alternatives in Table 500-42, as required by the Contract.

517.2.4 Geotextile : The use of geotextile as prescribed for Sl.No.7 in Table 500-42 shall conform to the requirements of Clause 703.3.

517.3 Construction Operations

517.3.1 Weather and seasonal limitations : Clause 501.5.1 shall apply.

517.3.2 Preparation of base : The base on which the SAM, SAMI or bitumen impregnated geotextile is to be laid shall be prepared, in accordance with Clause 501 and as directed by the Engineer. The surface shall be thoroughly cleaned either by using a mechanical brush or any other equipment / method approved by the Engineer. Dust removed in the process shall be blown off with compressed air.

517.3.3 Application of binder : The equipment and general procedures shall all be in accordance with the Manual for Construction and Supervision of Bituminous Works. The application temperature for modified binder shall be 160°-170°C. Binder for bitumen impregnated geotextile shall be applied according to Clause 502.4. The surface on which the binder is to be applied shall be dry.

Table 500-42 Quantity of Materials Required for 10 sq.m of Road Surface for Stress Absorbing Membrane

Sl.No.	Type and Width of Crack	Specification of SAM to be Applied	Quantity of binder Kg/10m²	Quantity of chipping
1.	Hair cracks and map cracks upto 3 mm width	Single coat SAM or 2nd coat of two coat SAM	8 – 10	0.10 m³ of 5.6 mm chips
2.	Map cracks or alligator cracks 3 mm to 6mm width	Single coat SAM	10 – 12	0.11m³ of 5.6 mm chips
3.	Map cracks or alligator cracks 6 mm to 9 mm width	Two coat SAM 1st coat 2nd coat	12 – 14 8 – 10	0.12 m³ of 5.6 mm and 11.2 mm chips in 1:1 ratio 0.10 m³ of 5.6 mm chips
4.	Cracks above 9mm width and cracked area above 50%	Two coat SAM 1st coat 2nd coat	14 – 16 8 – 10	0.12 m³ of 11.2 mm chips 0.10 m³ of 5.6 mm chips
5.	All types of cracks with crack width below 6 mm	Single coat SAM as interlayer	8 – 10	0.10 m³ of 5.6 mm chips
6.	All types of cracks with crack width above 6 mm	Single coat SAM As interlayer	10 – 12	0.10 m³ of 11.2 mm chips
7.	Bitumen Impregnated Geotextile			

Note: Binder quantities for bitumen impregnated geotextile shall be in the range 0.9 to 1.2 litres/m². Binder quantities outside this range are permitted according to the geotextile manufacturer's instructions and subject to the agreement of the Engineer.

517.3.4 Application of aggregates: The equipment and general procedures shall all be in accordance with the Manual for Construction and Supervision of Bituminous Works. Immediately after application of the modified binder, clean, dry aggregate shall be spread uniformly on the surface.

517.3.5 Sweeping : The surface of SAMs and SAMIs shall be swept to ensure uniform spread of aggregate and that there are no loose chips on the surface.

517.3.6 Two coat SAM or SAMI : Where a two coat SAM or SAMI is required by the Contract, the second coat shall be applied within 90 days of the first coat.

517.3.7 Geotextile placement : For bitumen impregnated geotextile, the requirements of Clause 703.4.4 shall apply.

517.4 Opening to Traffic

Traffic may be permitted over a SAM or SAMI 2 hours after rolling, but the speed shall be limited to 20km/h, until the following day. Speed control measures are to be approved by the Engineer, prior to laying.

517.5 Surface Finish and Quality Control of Work

The surface finish shall conform to the requirements of Clause 902.

For control on the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

517.6 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

517.7 Measurement for Payment

Each application of SAM, SAMI or bitumen impregnated geotextile shall be measured as finished work, for the area specified, in square metres.

517.8 Rate

The contract unit rate for SAM, SAMI or bitumen impregnated geotextile shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2.

518 MASTIC ASPHLAT

518.1 Scope

This work shall consist of constructing a single layer of mastic asphalt wearing course for road pavements and bridge decks.

Mastic asphalt is an intimate homogenous mixture of selected well-graded aggregates, filler and bitumen in such proportions as to yield a plastic and void less mass, which when applied hot can be trowelled and floated to form a very dense impermeable surfacing.

518.2 Materials

518.2.1 Binder : Subject to the approval of the Engineer, the binder shall be a paving/ Industrial grade bitumen meeting the requirements given in Table 500-43.

518.2.2 Coarse aggregates : The coarse aggregates shall consist of crushed stone, crushed gravel/shingle or other stones. They shall be clean, hard, durable, of fairly cubical shape, uncoated and free from soft, organic or other deleterious substances. They shall satisfy the physical requirements given in Table 500-13.

Table 500-43 Requirements for Physical Properties of Binder

Property		Test Method	Requirements
Penetration at 25°C		IS:1203	15 ± 5*
Softening point, °C		IS:1205	65 ± 10
Loss on heating for 5h at 163°C, % by mass	Max.	IS:1212	2.0
Solubility in trichloroethylene, % by mass	Min.	IS:1216	95
Ash (mineral matter), % by mass	Max.	IS:1217	1.0

* In cold climatic regions (temperature d”10°C), VG 40 grade bitumen may be used.

The percentage and grading of the coarse aggregates to be incorporated in the mastic asphalt depending upon the thickness of the finished course should be as specified in Table 500-44.

Fine aggregates : The fine aggregates shall be the fraction passing the 2.36 mm and retained on the 0.075 mm sieve consisting of crusher run screening, natural sand or a mixture of both. These shall be clean, hard, durable, uncoated, dry, and free from soft or flaky pieces and organic or other deleterious substances.

Filler : The filler shall be limestone powder passing the 0.075 mm sieve and shall have a calcium carbonate content of not less than 80 percent by weight when determined in accordance with IS:1514.

The grading of the fine aggregate inclusive of filler shall be as given in Table 500-45.

Table 500-44 Grade and Thickness of Mastic Asphalt Paving and Grading of Coarse Aggregates

Application	Thickness range (mm)	Nominal size of course aggregate (mm)	Course aggregate content, % by mass of total mix
Roads and carriageways	25–50	13	40±10
Heavily stressed areas i.e. Junctions and toll plazas	40–50	13	45±10
Nominal size of coarse aggregate		13 mm	
IS Sieve (mm)		Cumulative % passing by weight	
19		100	
13.2		88–96	
2.36		0-5	

Table 500-45 Grading of Find Aggregate (Inclusive of Filler)

IS Sieve	Percentage by weight of aggregate
Passing 2.36 mm but retained on 0.600 mm	0 – 25
Passing 0.600 mm but retained on 0.212 mm	10 – 30
Passing 0.212 mm but retained on 0.075 mm	10 – 30
Passing 0.075 mm	30 – 55

518.3 Mix Design

518.3.1 Hardness number : The mastic asphalt shall have a hardness number at the time of manufacture of 60 to 80 at 25°C prior to the addition of coarse aggregate and 10 to 20 at 25°C at the time of laying after the addition of coarse aggregate.

The hardness number shall be determined in accordance with the method specified in IS:1195-1978.

518.3.2 Binder content : The binder content shall be so fixed as to achieve the requirements of the mix specified in Clause 518.3.1 and shall be in the range of 14 to 17 percent by weight of total mix as indicated in Table 500-46.

Table 500-46 Composition of Mastic Asphalt Blocks without Coarse Aggregate

IS Sieve	Percentage by weight of mastic asphalt	
	Minimum	Maximum
Passing 2.36 mm but retained on 0.600 mm	0	22
Passing 0.600 mm but retained on 0.212 mm	4	30
Passing 0.212 mm but retained on 0.075 mm	8	18
Passing 0.075 mm	25	45
Bitumen Content % by mass	14	17

518.3.3 Job mix formula : The Contractor shall submit to the Engineer for approval at least one month before the start of the work the job mix formula proposed to be used by him for the work, indicating the source and location of all materials, proportions of all materials such as binder and aggregates, single definite percentage passing each sieve for the mixed aggregate and results of the tests recommended in the various Tables and Clauses of this Specification.

518.4 Construction Operations

518.4.1 Weather and seasonal limitations : The provisions of Clause 501.5.1 shall apply, except that laying shall not be carried out when the air temperature at the surface on which the Mastic Asphalt is to be laid is below 10°C.

518.4.2 Preparation of the base : The base on which mastic asphalt is to be laid shall be prepared, shaped and conditioned to the profile required, in accordance with Clause 501 or 902 as appropriate or as directed by the Engineer. In the case of a cement concrete base, the surface shall be thoroughly power brushed clean and free of dust and other deleterious matter. Under no circumstances shall mastic asphalt be spread on a base containing a binder which might soften under high application temperatures. If such material exists, the same shall be cut out and repaired before the mastic asphalt is laid.

518.4.3 Tack coat : A tack coat in accordance with Clause 503 shall be applied on the base or as directed by the Engineer.

518.4.4 Preparation of mastic asphalt : Preparation of mastic asphalt consists of two stages. The first stage shall be mixing of filler and fine aggregates and then heating the mixture to a temperature of 170°C to 210°C. Required quantity of bitumen shall be heated to 170°C to 180°C and added to the heated aggregated. They shall be mixed and

cooked in an approved type of mechanically agitated mastic cooker for some time till the materials are thoroughly mixed. Initially the filler alone is to be heated in the cooker for an hour and then half the quantity of binder is added. After heating and mixing for some time, the fine aggregates and the balance of binder are to be added and further cooked for about one hour. The second stage is incorporation of coarse aggregates and cooking the mixtures for a total period of 3 hours. During cooking and mixing care shall be taken to ensure that the contents in the cooker are at no time heated to a temperature exceeding 210°C.

Where the material is not required for immediate use it shall be cast into blocks consisting of filler, fine aggregates and binder, but without the addition of coarse aggregate, weighing about 25 kg each. Before use, these blocks shall be reheated to a temperature of not less than 175°C and not more than 210°C, thoroughly incorporated with the requisite quantity of coarse aggregates and mixed continuously. Mixing shall be continued until laying operations are completed so as to maintain the coarse aggregates in suspension. At no stage during the process of mixing shall the temperature exceed 210°C.

The mastic asphalt blocks (without coarse aggregate) shall show on analysis a composition within the limits as given in Table 500-46

The mix shall be transported to the laying site in a towed mixer transporter having arrangements for stirring and keeping the mix hot during transportation.

518.4.5 Spreading : The mastic asphalt shall be laid, normally in one coat, at a temperature between 175°C and 210°C and spread uniformly by hand using wooden floats or by machine on the prepared and regulated surface. The thickness of the mastic asphalt and the percentage of added coarse aggregate shall be in accordance with Table 500-44 or as specified by the Engineer. Where necessary, battens of the requisite dimensions should be employed. Any blow holes that appear in the surface shall be punctured while the material is hot, and the surface made good by further floating.

Laying surface over old existing bridge deck : Before laying bitumen over old existing bridge deck, the existing cross fall/camber, expansion joint members and water drainage spouts shall be carefully examined for their proper functioning in the bridge deck structure and any deficiency found shall be removed. Loose elements in the expansion joint shall be firmly secured. The cracks in the concrete surface, if any, shall be repaired and filled up properly or replaced by new concrete of specified grade before laying the bitumen mastic over bridge deck.

Laying over new bridge deck : New concrete bridge deck which is not in camber/cross fall shall first be provided with required camber and cross fall by suitable concrete or

bituminous treatment. In case of laying over concrete surface, following measures shall be taken :

1) For proper bond with new concrete deck, surface shall be roughened by means of stiff broom or wire brush and it shall be free from ridges and troughs.

2) A thin bituminous tack coat (with bitumen of grade 60/70) shall be applied on the concrete deck before pouring mastic. The quantity of bitumen for tack coat shall not exceed 5-6 kg per 10 sq.m.

3) On surface in longitudinal slope, after applying tack coat, chicken-mesh reinforcement of 1.5 mm dia steel wire with hexagonal or rectangular openings of 20-25 mm shall be placed and held properly in position on the concrete surface before pouring mastic.

518.4.6 Joints : All construction joints shall be properly and truly made. These joints shall be made by warming existing mastic asphalt by the application of an excess quantity of the hot mastic asphalt mix which afterwards shall be trimmed to leave it flush with the surfaces on either side.

518.4.7 Surface finish : The mastic asphalt surface can have poor skid resistance after floating. In order to provide resistance to skidding, the mastic asphalt after spreading, while still hot and in a plastic condition, shall be covered with a layer of stone aggregate. This aggregate shall be 13.2 mm size (passing the 19.0 mm sieve and retained on the 6.7 mm sieve) or 9.5 mm size (passing the 13.2 mm sieve and retained on the 6.7 mm sieve) subject to the approval of the Engineer. Hard stone chips, complying with the quality requirements of Table 500-18, shall be precoated with bitumen at the rate of 2 ± 0.4 percent of VG 30 grade. The addition of 2 percent of filler complying with Table 500-8 may be required to enable this quantity of binder to be held without draining. The chips shall then be applied at the rate of 0.005 cu.m per 10 sq.m and rolled or otherwise pressed into the surface of the mastic layer when the temperature of the mastic asphalt is not less than 100°C.

518.5 Opening of Traffic

Traffic may be allowed after completion of the work when the mastic asphalt temperature at the mid-depth of the completed layer has cooled to the daytime maximum ambient temperature.

518.6 Surface Finish and Quality Control of Work

The surface finish of the completed construction shall conform to the requirements of Clause 902.

For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

The surface of the mastic asphalt, tested with a straight edge 3 cm long, placed parallel to the centre line of the carriageway, shall have no depression greater than 7mm. The same shall also apply to the transverse profile when tested with a camber template.

518.7 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

518.8 Measurement for Payment

Mastic asphalt shall be measured as finished work in square metres at a specified thickness, or by weight in tonnes as stated in the Contract.

518.9 Rate

The contract unit rate for mastic asphalt shall be payment in full for carrying out the required operations including full compensation for all components listed under Clause 501.8.2.2.

519 BITUMINOUS COLD MIX (INCLUDING GRAVEL EMULSION)

519.1 The Design Mix

Bituminous Cold Mix consists of a mixture of unheated mineral aggregate and emulsified or cutback bitumen. This Specification deals only with plant mix (as opposed to mixed-in-place). Two types of mix are considered, namely Designed Cold Mix. The Design Mix procedure shall be used unless the Recipe Mix procedure is specifically approved by the Engineer.

519.2 Designed Col Mix

This Specification is based on the Asphalt Institute Manual MS-14, which contains additional information for guidance. These mixes are considered suitable for use as base course, appropriate to their stability, in new work or major repair work.

519.2.1 Materials

519.2.1.1 Binder : The binder shall be a bituminous emulsion as specified in ASSHTO M 140 (ASTM D977)* or AASHTO M 208 (ASTM D2397)*, namely MS-2, MS2h, HFMS-2, HFMS-2h, HFMS-2s, SS-1, SS-1h, CMS-2, CMS-2h, CSS-1 and CSS-1h. Alternatively,

a cutback bitumen as specified in AASHTO M 82 (ASTM D2027) or ASTM D 2026, namely MC 70, 250, 800 and 3000 and SC 250, 800 and 3000 may be used, or, if approved by the Engineer, an equivalent material which conforms with IS:8887 and IS:217.

A general guide for the use of these binders is given in Table 500-47 and in the Manual for Construction and Supervision of Bituminous Works. However, the final selection shall be made only after laboratory evaluation with the aggregates to be used.

Table 500-47 Uses of Bitumen in Cold Mix

Type of Construction	Emulsified Bitumen									Cutback Bitumen						
	Anionic					Cationic				Medium Curing (MC)				Slow Curing (SC)		
Cold-Laid Plant Mix Pavement Base and Surfaces	MS-2, HFMS-2	MS-2h, HFMS-2h	HFMS-2s	SS-1	SS-1h	CMS-2	CMS-2h	CSS-1	CSS-1h	70	250	800	3000	250	800	3000
Open-Graded Aggregate	*	*				*	*									
Well-graded Aggregate			*	*	*			*	*		*	*	*	*	*	*
Patching, Immediate Use				*	*			*	*		*	*			*	
Patching, Stockpile											*	*		*	*	

The binder with the highest residual viscosity at ambient temperatures that can reasonably be handled by the mixing and laying equipment proposed shall be used.

519.2.1.2 Aggregates : The aggregates shall comply with the requirements of Clause 504.2.2. and 504.2.3. If the aggregates are not properly coated with anionic emulsion or cutback bitumen, a small amount of hydrated lime, an approved antistripping agent (see Appendix 5) or a change to cationic emulsion shall be proposed by the Contractor, for the approval of the Engineer.

519.2.1.3 Aggregate grading and binder content : The combined aggregate grading for the particular mixture, when tested in accordance with IS:2386 Part I, (wet sieving method), shall fall within the limits shown in Table 500-48.

519.2.2 Mix Design

519.2.2.1 Requirements for the mixture : Apart from conformity with the grading and quality requirements for individual ingredients, the mix shall meet the requirements set out in Table 500-49.

Table 500-48 Aggregate Grading and Bitumen Content

Nominal maximum size (mm)	9.5	13.2	19.0	26.5
Allowable thickness (mm)	25-35	36-50	51-75	76-100
IS Sieve (mm)	Cumulative % by weight of total aggregate passing			
37.5	-	-	-	100
26.5	-	-	100	90-100
19.0	-	100	90-100	-
13.2	100	90-100	-	56-80
9.5	90-100	-	60-80	-
4.75	60-80	45-70	35-65	25-59
2.36	35-65	25-55	20-50	19-45
0.30	6-25	5-20	3-20	5-17
0.075	2-10	2-9	2-8	1-7
	[1]Guide to binder content, percent by weight of total mix			
Cutback	Min 4 to Max 6			
mulsion	Min 7 to Max 10			

[1]To be determined by the modified Marshall Test.

Table 500-49 Mix Requirements for Designed Cold Mix

Parameter	**Emulsion[1]**	**Cutback[2]**
Minimum Stability (kN at 22.2°C) Emulsion (kN at 25°C) Cutback	2.2 for paving	2.2 for maintenance 3.3 for paving
Percent maximum stability loss on soaking	50 [3]	25[4]
Minimum flow (mm)	2	2
Compaction level (number of blows)	50	75
Per cent air voids	3-5[5]	3.5
Per cent voids in mineral aggregate (VMA)	See Table 500-50	
Per cent minimum coating[6]	50	

Notes [1]Using Marshall method for emulsified asphalt-aggregate cold mix design". Appendix F, MS-14

[2]Using "Marshall method for cut-back asphalt-aggregate cold mix design:, Appendix H, MS-14

[3]With vacuum saturation and immersion

[4]Four days soak at 25°C.

[5]Refers to total voids in the mix occupied by air and water

[6]Coating Test, Appendix F, MS-14.

Table 500-50 Minimum Percent Voids in Mineral Aggregate (VMA)

Nominal Maximum Particle Size IS Sieve (mm)	Minimum VMA (per cent)
9.5	16.0
12.5	15.0
19.0	14.0
25.0	13.0
37.5	12.0

519.2.2.2 Binder content : The binder content shall be optimized to achieve the requirements of the mix set out in Table 500-41. The method adopted shall be that described in Appendix F and H of Asphalt Institute's Manual, MS-14.

519.2.2.3 Job mix formula : The Contractor shall submit to the Engineer for approval at least one month before the start of the work, the job mix formula proposed for use in the works together with the following details:

i) Source and location of all materials;

ii) Proportions of all materials expressed as follows where each is applicable:

a) Binder, as percentage by weight of total mix;

b) Coarse aggregate/fine aggregate as percentage by weight of total aggregate;

iii) A single definite percentage passing each sieve for the mixed aggregate;

iv) The results of tests enumerated in Table 500-49 as obtained by the Contractor;

v) Test results of the physical characteristics of the aggregates to be used;

vi) Spraying temperature of binder if appropriate.

While working out the job mix formula, the Contractor shall ensure that it is based on a correct and truly representative sample of the materials that will actually be used in the work and that the mix and its different ingredients satisfy the physical and strength requirements of these Specifications.

Approval of the job mix formula shall be based on independent testing by the Engineer for which samples selected jointly with the Engineer of all ingredients of the mix shall be furnished by the Contractor as required by the former.

The approved job mix formula shall remain effective unless and until modified by the Engineer. Should a change in the source of materials be proposed, a new job mix formula shall be established by the Contractor and approved by the Engineer before actually using the materials.

519.2.2.4 Permissible variation from the job mix formula : It shall be the responsibility of the Contractor to produce a uniform mix conforming to the approved job mix formula, subject to the permissible variations of the individual percentages of the various ingredients in the actual mix from the job mix formula to be used, within the limits as specified in Table 500-12 and 500-20. These variations are intended to apply to individual specimens taken for quality control tests in accordance with Section 900.

519.2.3 Construction operations

519.2.3.1 Weather and seasonal limitations : Construction with cold mix must not be undertaken when ambient temperatures below 10°C are expected, during rain, in standing water, or generally when poor weather is predicted. Bitumen emulsions and cutbacks depend on the evaporation of water and/or solvent for the development of their curing and adhesion characteristics. Cold weather, rain and high humidity slow down the rate of curing. Extra manipulation may be required to remove volatiles in cool and humid conditions. Wind increases the rate of evaporation.

519.2.3.2 Preparation of the base : The base on which cold mix is to be laid shall be prepared, shaped and leveled to the required profile in accordance with Clauses 501 and 902 as appropriate, and a prime coat, where specified, shall be applied in accordance with Clause 502 or as directed by the Engineer.

519.2.3.3 Tack coat : A tack coat in accordance with Clause 503 shall be applied over the base on which the cold mix is to be laid where specified in the Contract.

519.2.3.4 Preparation and transportation of the mix : Mixing can be carried out using one of the following types of mixer, which is provided with equipment for spraying the binder at a controlled rate and, if necessary, for heating the binder to a temperature at which it can be applied uniformly to the aggregate:

a) rotary drum type concrete mixer;

b) single or twin shaft concrete or macadam mixer;

c) batch or continuous type mixer without dryer or screens other than a scalping screen.

Sufficient number of haul trucks with smooth, clean beds should be available to ensure continuous operation of the mixing plant. The type of truck used for transporting the mixture from the mixer to the road site must suit to the Contractor’s nominated laying procedure methodology.

519.2.3.5 Spreading : Designed cold mix shall be placed only when the specified density can be obtained. The mix shall not be placed on any wet surface or when weather conditions will otherwise prevent its proper handling or finishing.

If spreading by motor grader, the grader must have a blade that is straight and sharp and long enough to ensure finishing to close, straight, transverse tolerances and all joints and linkages must be in good condition. The grader must be heavy enough to hold the blade firmly and uniformly on the surface while spreading the mix.

If climatic conditions and aggregate grading permit evaporation of moisture or volatiles without aeration by manipulation, a conventional self-propelled asphalt paver shall be used to place designed cold mix.

Other methods of spreading may be used as approved by the Engineer.

519.2.3.6 Compaction: Initial compaction of the laid material shall be carried out using a pneumatic-tyred roller of a weight appropriate to the layer thickness to be compacted with single layer thickness being 25-100 mm and all compaction being in accordance with Clause 501.6 and 501.7. Smooth tyres shall be used. Final rolling and smoothening of the surface should be completed using steel wheel rollers. The Contractor shall demonstrate at laying trials that his proposed laying and compaction methods can achieve a satisfactory result.

519.2.4 Opening to traffic : Traffic shall not be allowed to run on new work until all the water or volatiles in the mix have evaporated, as determined by the Engineer. The rate of evaporation will be influenced by the temperature, humidity and wind conditions.

519.2.5 Surface finish and quality control of work: The surface finish of construction shall conform to the requirements of Clause 902. For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

519.2.6 Arrangements for traffic: During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

519.2.7 Measurement for payment: Designed Cold Mix shall be measured as finished work, for the area covered, in cubic metres, by weight in metric tonnes, or by square metres at a specified thickness as specified in the Contract.

519.2.8 Rate : The contract unit rate for Designed Cold Mix shall be payment

in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2. The rate shall cover the provision of the specified grade of cutback in the mix at 5 per cent of the weight of the total mix or emulsion at 8 percent of the weight of the total mix. However any variation in quantity of binder will be assessed on the basis of the amount agreed by the Engineer and the payment adjusted, plus or minus, as per the rate for cutback or emulsion quoted in the Bill of Quantities.

519.3 Recipe Cold Mix

This Specification is based on BS434:Part 2:1984 which contains additional information. These are premixes made with emulsion binder which are laid immediately after mixing and while the emulsion is still substantially in an unbroken state. These mixes are considered suitable for emergency and repair work and temporary road surface improvement.

519.3.1 Materials

519.3.1.1 Binder : Emulsions of sufficient stability for mixing with the particular graded aggregate should be used. Grades of emulsions quoted are in accordance with BS434: Part 1:1984 but comparable grades to IS or AASHTO specifications may be used. Guidance on selection of an appropriate grade of emulsion is given in the Manual for Construction and Supervision of Bituminous Works. The corresponding grades in IS: 8887 are only broadly classified as RS, MS and SS (further sub-classification is not available at present).

519.3.1.2 Aggregates : Any normal, clean, but not necessarily dry, aggregate can be used, provided that it has sufficiently high crushing strength with regard to the traffic to be carried. Typical gradings are given in Table 500-51.

519.3.1.3 Aggregate grading and binder content : When tested in accordance with IS:2386 Part 1 (wet sieving methods) the combined aggregate grading for the particular mix shall fall within the limits shown in Table 500-51. The grade and range of quantity of emulsion are also indicated in this table. The actual quantity of emulsion to be used shall be approved by the Engineer after seeing the results of trial mixes made in the laboratory.

519.3.2 Construction operations

519.3.2.1 Weather and seasonal limitations : Construction with cold mix must not be undertaken when ambient temperatures below 10°C are expected or when poor weather is predicted. Bitumen emulsion and cutbacks depend on the evaporation of water and/or solvent for the development of their curing and adhesive characteristics. Cold weather, rain, and high humidity slow down the rate of curing. Extra manipulation may be required to remove volatiles in cool or humid conditions. Wind increases the rate of evaporation.

519.3.2.2 Preparation of base : The base on which the cold mix is to be laid shall be prepared shaped and graded to the required profile in accordance with Clauses 501 and 902 as appropriate, and a prime coat if specified in the contract, or required by the Engineer, shall be applied in accordance with Clauses 502, or as directed by the Engineer.

Table 500-51 Composition of Recipe Mixes

Nominal size (mm) and Type of Macadam	**40 Single course**	**40 Open textured base course**	**14 Open textured wearing course**	**6 Medium textured wearing course**	**- Fine coated**
Allowable Thickness (mm)	75-100	75-100	31-50	21-30	15-20
IS Sieve Size mm	Cumulative % by weight of total aggregate passing				
45	100	100	-	-	-
37.5	90-100	90-100	-	-	-
26.5	55-90	55-85	-	-	-
19	-	-	100	-	-
13.2	35-55	15-35	90-100	-	-
9.5	-	-	55-75	100	-
6.3	20-30	-	25-45	90-100	100
3.35	10-20	0-10	15-25	45-65	-
2.36	-	-	-	-	75-100
1.18	-	-	-	10-30	-
0.60	-	-	-	-	30-55
0.30	2-10	-	-	-	-
0.15	-	-	-	-	10-25
0.075	-	-	2-6		5-15
Emulsion grade and quantity					
Generally	A2 – 57 (4z)	Or	A2 – 50 (4)		
Under some Circumstances	-	-	-	A_3	A_3
Quantity (1) Litres/tonne	55 to 70	45 to 65	70 to 90	85 to 100	100 to (2) (3) 120

Notes : 1) For pricing purposes, the lower quantity in these ranges should be assumed.

2) With coarser grading quantity may sometimes be reduced to 80 litres/tonne and with finer grading it may sometimes be increased up to 135 litres/tonne

3) Use 0 – 70 litres/tonne of water as necessary

4) A2-50 and A2-57 are British grades of emulsion and their grading system is explained in the Manual.

519.3.2.3 Tack coat : A tack coat in accordance with Clause 503 shall be applied over the base on which the cold mix is to be laid if specified in the Contract or required by the Engineer.

519.3.2.4 Preparation and transportation of the mix : Mixing shall be carried out using one of the following types of mixer, which is provided with equipment for spraying the binder at a controlled rate, and, if necessary, for heating the binder to a temperature at which it can be applied uniformly to the aggregate:

a) rotary drum type concrete mixer;

b) single or twin shaft concrete or macadam mixer;

c) batch or continuous type mixer without dryer or screens than a scalping screen.

Sufficient number of haul trucks with smooth, clean beds should be available to ensure continuous operation of the mixing plant. The type of truck used for transporting the mix from the mixer to the road site must suit the chosen laying procedure.

519.3.2.5 Spreading : The mixed material should be spread immediately after preparation. The mix shall be placed only when the specified density can be obtained. The mixture shall not be placed on any wet surface or when weather conditions will otherwise prevent its proper handling or finishing.

If spreading by motor grader, the grader must have a blade that is straight and sharp and long enough to ensure finishing to close straight transverse tolerances and all joints and linkages must be in good condition. The grader must be heavy enough to hold the blade firmly and uniformly on the surface while spreading the mix. On surface courses, the tyres must be smooth.

The methodology for spreading shall be approved by the Engineer prior to laying, and if required a laying trial conducted to prove that the laying method is satisfactory before approval.

519.3.2.6 Compaction : Initial compaction of the laid material shall be carried out using a pneumatic-tyred roller of a weight appropriate to the layer thickness to be compacted with single layer thicknesses being 25-100 mm and all compaction being in accordance with Clause 501.6 and 501.7. Smooth tyres shall be used. Final rolling and smoothening of the surface should be completed using steel wheel rollers. The Contractor shall demonstrate at laying trials that his proposed laying and compaction methods can achieve satisfactory result.

519.3.3 Opening to traffic : Traffic shall not be allowed to run on new work until all the water or volatiles in the mix have evaporated. The rate of evaporation will be influenced by the temperature, humidity and wind conditions.

519.3.4 Surface finish and quality control of work : The surface finish of construction shall conform to the requirements of Clause 902. For control of the quality of materials and the works carried out, the relevant provisions of Section 900 shall apply.

519.3.5 Arrangements for traffic : During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

519.3.6 Measurement for payment : Recipe Cold Mix shall be measured as finished work, for the area instructed to be covered, in cubic metres, by weight in metric tonnes, or in square metres at a specified thickness, as specified in the Contract.

519.3.7 Rate

The contract unit rate for Recipe Cold Mix shall be payment in full for carrying out the required operations including full compensation for all components listed in Clause 501.8.8.2. The rate shall cover the provision of the specified grade of emulsion at the lower quantity in the range for each type of mix indicated in Table 500-48. However any variation of quantity in emulsion will be assessed on the basis of the amount agreed by the Engineer and the payment adjusted plus or minus, as per the rate for emulsion quoted in the Bill of Quantities.

520 RECYCLING OF BITUMINOUS PAVEMENT

520.1 Scope

This work covers the recycling of existing bituminous pavement materials to upgrade an existing bituminous pavement which has served its initially intended purpose. The work shall be performed on such widths and lengths as may be directed by the Engineer and may consist of pavement removal, stockpiling of materials from the old pavement, addition of new bitumen and untreated aggregates in the requisite proportions, mixing, spreading and compaction of the blended materials.

Recycling processes can be categorized into in-situ recycling (where processing takes place on site), and central plant recycling (where reclaimed material is processed off site). The processes can be further sub-divided into hot and cold processes. This specification covers the hot process only. However, reclaimed aggregates from cold in-situ recycling can be used in the Bituminous Cold Mix treatment covered in Clause 519, subject to the resultant mixes achieving the specified standards.

520.2 Reclaimed Bituminous Materials for Central Plant Recycling

520.2.1 Proportion of reclaimed materials less than 10 percent : If not more than 10 percent of reclaimed bituminous material in to be used is the production of

bituminous macadam or dense graded bituminous base or binder course material, then Clauses 520.2.2 to 520.2.9 do not apply. However :

a) all reclaimed bituminous material shall be pre-treated before use such that the material is homogeneously mixed and the maximum particle size of reclaimed material does not exceed 40 mm.

b) the mixed material shall comply with the requirements of Clauses 504 or 505 as appropriate.

520.2.2 Proportions of reclaimed materials greater than 10 percent : Reclaimed bituminous material of an amount greater than 10 per cent, may be used in the production of bituminous macadam and dense graded bituminous base and binder course material, subject to the requirements of Clauses 520.2.3 to 520.2.9 and subject to the satisfactory completion of full trial investigations in respect of all related materials, layer thickness, machine operations and finished works on a case by case basis entirely at the Contractor's cost and subject to the approval of the Engineer. For estimating purposes, a maximum amount not greater than 30 percent reclaimed bituminous material should be assumed.

520.2.3 Materials for recycled pavement : The recycled materials shall be a blend of reclaimed and new materials proportioned to achieve a paving mixture with the specified engineering properties. The reclaimed materials shall be tested and evaluated to find the optimum blend meeting the mixture requirements. Such testing and evaluation shall be carried out on representative sample, either cores sampled from the carriageway or samples taken from stockpiles in accordance with current practice. The sampling frequency should be sufficient to determine how consistent the reclaimed material is and to provide representative samples for composition analysis and measurement of properties of recovered binder. As an absolute minimum, one sample to represent 500 m two lane carriageway shall be taken.

520.2.4 Bitumen extraction : The procedure described in ASTM D-2172 shall be used to quantitatively separate aggregates and bitumen from any representative sample of reclaimed bituminous pavement.

520.2.5 Aggregate evaluation : Mechanical sieve analysis (IS:2386, Part I, wet sieving method) shall be performed on the aggregate portion of the reclaimed bituminous pavement sample to determine the grading. It is essential that the reclaimed materials to be recycled are consistent, as variable materials will cause problems with the control of quality and impede the efficiency of the recycling operation. Suitable sources of consistent material either in existing pavements, from stockpiled of known origin or from another suitable source, before a decision can be made on the optimum percentage of reclaimed material.

After selecting the proportion of reclaimed materials to be recycled, the grading of the mixture may need adjustment, to meet Specification requirements, by the addition of selected aggregate sizes.

520.2.6 Evaluation of bitumen : When the amount of reclaimed bituminous materials to be used in the mixture exceeds 10 percent, the penetration value of the recovered binder from the reclaimed bituminous material, before mixing, shall exceed 15 pen, after recovery of binder in accordance with the requirements of BS:2000 :Part 397, when tested in accordance with IS :1203. Provided the above requirement is met, hardening of the old binder, during the original mixing process or through ageing, can be compensated for by adding softer bitumen, to obtain the appropriate final grade of binder.

The determination of the type and amount of binder required to be added in the final mix is essentially a trial and error procedure.

After mixing with recycled materials, the binder recovered from the mixture shall have a recovered penetration value not less than the value specified in Table 500-51.

Table 500-51 Minimum Recovered Binder Penetration of Recyled Mixture

Specified Grade of Binder (Penetration)	Minimum Recovered Penetration Value of Binder after Mixing
45	27
65	39
90	54

520.2.7 Rejuvenators: The use of rejuvenators, and a test to measure their effectiveness, is given in Clause 520.6.3.

520.2.8 Untreated aggregates : If necessary, fresh untreated aggregates shall be added to the reclaimed bituminous pavement to produce a mix with the desired grading. The aggregate shall be checked for quality requirements in accordance with Table 500-7 or Table 500-13 as appropriate. Reclaimed aggregate, if any, or any aggregate normally used for the desired bituminous mix, or both, may be used for this purpose.

520.2.9 Combined aggregate grading : The blend reclaimed and new aggregate shall meet the grading criteria specified in the relevant parts of Clause 505 or 506, as appropriate and as approved by the Engineer. The blend of aggregates shall be checked for resistance to stripping as specified in Table 500-7 or 500-13 as appropriate.

520.3 Mixture Design

The combined aggregate grading and binder content shall comply with the relevant tables in Clauses 505 or 506 for dense graded bituminous mixes the mix design shall also comply with the requirements of Table 500-10. There may be a variation on three to four sieves with respect to percent passing, the permissible variation shall not exceed 3 to 4 percent per sieve.

520.4 Reclaiming Old Pavement Materials

The removal of pavement materials to the required depth shall be accomplished either at ambient temperature (cold process) or at an elevated temperature (hot process), as approved by the Engineer.

520.4.1 Cold removal process : In the cold process, the ripping and crushing operations shall be carried out using scarifiers, grid rollers, or rippers or by any other means as directed by the Engineer. The removed materials shall be loaded and hauled for crushing to the required size as directed by the Engineer. Alternatively, cold milling or planning machines can be used to reclaim bituminous pavement to controlled depths. Thereafter the bituminous layers are removed, any remaining aggregate materials that are to be incorporated in the recycled hot mix shall be scarified and removed. When the pavement material removal is completed, any drainage deficiencies shall be corrected. After that, the base/sub-base as the case may be shall be cut, graded and compacted to the required profile and density.

520.4.2 Hot removal process : In the hot process, the road surface shall be heated, by any suitable means approved by the Engineer, before scarification. A self propelled plant shall be used, and a milling drum that follows the planer removes the heated soft bituminous layer. The depth, width and speed of travel shall be adjusted to suit specific requirements as directed by the Engineer. During the heating process, the surface temperature of the road shall not exceed 200°C for more than 5 minutes.

520.4.3 Stockpiling : In the cold process, the reclaimed bituminous pavement material shall be stockpiled with height of stockpiles not exceeding 3 m. The reclaimed untreated aggregate base/sub-base material shall be stockpiled in the same manner as new aggregate. The number and location of stockpiles shall be carefully planned for efficient operation of the hot-mix plant.

520.5 Mixing and Laying

The requirements of Clause 506.3 or 505.4, as appropriate shall apply.

520.6 In Situ Recycling – The Remix and Repave Processes

These processes are suitable for the production of bituminous concrete wearing course in accordance with the provisions of Clause 508.

520.6.1 Scope: In the process of repaving, the existing surface is preheated and scarified but the scarified material is not removed. A layer of fresh bituminous mix material prepared in the integrated mixing unit of the plant is then spread evenly on the scarified surface to give a uniform profile. The spread material should be compacted as soon as possible after laying. In the process, the total thickness of the pavement is increased by up to 50mm.

In the remix process, the scarified material should be taken from the mixing unit of the plant where it is recycled with fresh binder, aggregate and recycling agent. Then the recycled mixture is spread on the preheated surface and tamped and compacted to the required profile.

520.6.2 Heating and scarifying : Surfaces to be treated shall be heated by plant with surfaces insulated and fully enclosed. The heated width of surfacing shall exceed the scarified width by at least 75 mm on each side, except against the edge of the carriageway or kerb face. When new surfacing material is spilled onto the road surface it shall be removed before the existing surface is heated and scarified. Areas of unscarified material shall not exceed 50 mm x 50 mm.

The depth of scarification shall be such that the bottom of the scarified layer is parallel to and below the finished road surface level by the thickness of wearing course material specified. A tolerance of ±6 mm is permissible.

Where street furniture and other obstructions occur, these shall be suitably protected or removed and the void covered. Surface dressing and large areas of road markings shall be removed by milling, planning scarifying or by similar approved processes.

The heated surface shall be evenly scarified to comply with the requirements of this Clause. When street furniture is left in place or raised, the adjacent area shall be scarified by other means, with the material either left in place or removed, prior to passage of the machine. If furniture needs to be repositioned on completion of work, the new wearing course material shall be used to make good the road surface for a maximum width of 200 mm around the obstruction.

During the reheating process, the surface temperature of the road shall not exceed 200°C for more than 5 minutes.

520.6.3 Rejuvenator: For Remix, when required, rejuvenator shall be uniformly sprayed across the fullwidth of the processed material. The machine shall incorporate a

meter for continuous verification of quantities which shall be within ±5% of the specified rate. The volume of rejuvenator shall vary in relation to the operating speed of the machine, which shall be r4elated to the volume of material mixed or scarified.

The rejuvenator shall be a non-emulsified aromatic extract. Its properties shall be verified using the Rolling Thin Film Oven Test.

Rejuvenation of the existing pavement may also be performed by adding new hot-mix bituminous material containing a soft binder for restoring the binder in the existing pavement to the required viscosity. Use of rejuvenating oil may be resorted to in case the target values of viscosity, penetration and softening are not met.

520.6.4 Mixing : When required, new hot-mix material shall be mixed with the heated and scarified road pavement material in a pugmill within the Remix machine, observing the mixing temperatures specified in Table 500-15.

After mixing, the recycled bituminous materials shall be automatically led to a finishing unit, which spreads and levels the mixture to the specified thickness and cross-section. The new bituminous concrete wearing course shall comply with Clause 508.

520.6.5 Additional material (general) : The proportion of new hot-mix bituminous material, and the proportion of existing bituminous pavement material shall be as directed by the Engineer, together with the amount the road surface level is to be raised (if any).

The type and quantity of the new hot-mix material shall be determined by using the Marshall Mix Design procedure specified in the Asphalt Institute Manual MS-2, before work commences. Remix designs shall incorporate the stated proportion of material sampled from the existing road surface.

When additional coarse or fine aggregate or filler are required to be added, they shall comply with the requirements of Clause 508.2. The amount of additional coarse or fine aggregate or filler to be added to the existing bituminous pavement material shall be notified to the Engineer.

520.6.6 Additional aggregate (remix process) : The coarse aggregate, fine aggregate and filler added to the Remixed material shall comply with the requirements of Clause 508.2.

520.6.7 New surfacing (repave and remix/repave processes) : New surfacing material shall be bituminous concrete wearing course complying with Clause 508, or other wearing course material approved by the Engineer.

The new surfacing material shall be laid on, and compacted with, the reprofiled surfacing, which shall be at a temperature within the range of 100°C to 150°C.

520.6.8 Binder : The binder shall be recovered from samples taken from each layer of material laid. The method of recovery shall be in accordance with BS:2000: Part 397 or an equivalent test. The penetration of the binder shall be in the range 35-70 pen.

520.6.9 Mixture design : The surfacing material shall be sampled from the paver hopper or augers. Care shall be taken that only the material forming the new surface layer is sampled. The sample shall be reduced at site by rifling or quartering to approximately 5 kg and placed loose in an air-tight container.

The sample shall only be reheated once whilst within the container. As soon as the sample reaches the required temperature, the reheated material shall be remixed and three Marshall test specimens prepared in accordance with the procedures specified in MS-2.

The bulk density of each specimen shall be measured before Marshall Stability testing. The mean stability and flow of the three specimen measured in accordance with the procedures specified in MS-2, shall comply with the requirements of Table 500-10.

Finally the three Marshall specimens shall be combined and the maximum theoretical specific gravity (G_{mm}) of the mix is determined in accordance with ASTM D 2041. This maximum theoretical specific gravity (G_{mm}) corresponds to 0% air voids in the mix. The actual bulk specific gravity of a Marshall specimen determined in the Laboratory (G_{mb}) will naturally be less the G_{mm}. The percent air voids (Pa) in the specimen of the compacted mixture given by $P_a=(G_{mm}–G_{mb}x100)/G_{mm}$ should meet the requirements of air voids laid down in Table 500-10.

520.7 Opening to Traffic

For recycled material forming the base or binder course layer, Clause 504.5 or 505.5 shall apply as appropriate. For recycled material forming the wearing course layer, Clause 508.5 shall apply.

520.8 Surface Finish and Quality Control

The surface finish of the completed construction shall conform to the requirements of Clause 902.

For control of the quality of materials and the works carried out the relevant provisions of Section 900 shall apply.

520.9 Arrangements for Traffic

During the period of construction, arrangements for traffic shall be made in accordance with the provisions of Clause 112.

520.10 Measurement for Payment

The recycled pavement work shall be measured in cubic metres or tonnes of finished work as stated in the Contract.

520.11 Rate

The contract unit rate for recycled pavement shall be payment in full for carrying out the required operations including full compensation for all items as Clause 501.8.8.2.

521 SUPPLY OF STONE AGGREGATES FOR PAVEMENT COURSES

521.1 Scope

This Clause shall apply to the supply of stone aggregates only. The work shall consist only of collection, transportation and stacking the stone aggregates and stone filler for subsequent use in pavement courses. The actual work of laying the pavement courses shall, however, be governed by the individual Specification Clause for the actual work, given elsewhere in these Specifications. The size and quantities of the aggregates to be supplied shall be so selected by the Engineer that the grading requirements set forth in the individual Specification Clauses for the pavement courses, for which the supply is intended, are satisfied.

All the materials shall be procured from approved sources and shall conform to the physical requirements, specified in the respective Specification Clauses for the individual items given elsewhere in these Specifications.

521.2 Sizes of Stone Aggregates

The stone aggregates shall be designated by their standard sizes in the Contract and shall conform to the requirements shown in Table 500-53.

521.3 Stacking

521.3.1 Coarse Aggregates

Only the aggregates satisfying the Specifications requirements shall be conveyed to the roadside and stacked. Each size of aggregate shall be stacked separately. Likewise, materials obtained from different quarry sources shall be stacked separately and in such a manner that there is no contamination of one source with another.

Table 500-53 Size Requirements for Coarse Stone Aggregates

S.No.	Nominal size of aggregate	Designation of sieve through which the aggregates shall wholly pass	Designation of sieve on which the aggregates shall be wholly retained
i)	75 mm	106 mm	63 mm
ii)	63 mm	90 mm	53 mm
iii)	45 mm	53 mm	26.5 mm
iv)	26.5 mm	45 mm	22.4 mm
v)	22.4 mm	26.5 mm	13.2 mm
vi)	13.2 mm	22.4 mm	11.2 mm
vii)	11.2 mm	13.2 mm	6.7 mm
viii)	6.7 mm	11.2 mm	2.8 mm

521.3.2 Fine Aggregate : As stated in the individual relevant Specification Clauses.

The aggregates shall be stacked clear of the roadway on even clear hard ground, or on a platform prepared in advance for the purpose by the Contractor at his own cost and in a manner that allows correct and ready measurement. If the stockpile is placed on ground where the scraping action of the loader can contaminate the material with underlying soil, then the stockpile shall be rejected by the Engineer. Materials shall not be stacked in locations liable to inundation or flooding.

The dimensions of the stockpiles and their locations shall be approved by the Engineer. Where the material is improperly stacked, the Engineer shall direct complete re-stacking of the materials in an approved manner at the Contractor's cost.

Stone filler shall be supplied in a dry state in bags or other suitable containers approved by the Engineer and shall be protected from the environment, so as to prevent deterioration in quality.

521.4 Quality Control of Materials

The Engineer shall exercise control over the quality of the materials so as to ascertain their conformity with the Specifications requirements, by carrying out tests for the specified properties.

Testing shall be to the following frequencies and the Engineer may, at his discretion, direct these to be modified according to requirements:

Coarse and fine aggregate	:	One test for each specified property per 50 m^3 of stone aggregates.
Stone filler	:	One test for each specified property for every five tonnes, subject to a minimum of one test for each consignment.

Materials shall only be brought to site from a previously tested and approved source, and any materials not conforming to the requirements of the Specification shall be rejected by the Engineer and removed from the work site at the cost of the Conctractor.

521.5 Measurement for Payment

Coarse and fine aggregates supplied to the site shall be paid for in cubic metres. The actual volume of the aggregates to be paid for shall be computed after deducting the specified percentages in Table 500-54, from the volume computed by stack measurements, to allow for bulking.

Unless otherwise directed by the Engineer, measurements shall not be taken until sufficient materials for use on the road have been collected and stacked. Immediately after measurement, the stacks shall be marked by white wash or other means as directed by the Engineer.

Stone filler as delivered to the site shall be measured in tonnes.

Table 500-54 Percent Reduction In Volume of Aggregates

S. No.	Standard size of aggregates	Percentage reduction in volume Computed by stack measurements to arrive at the volume to be paid for
1.	75 mm and 63 mm	12.5
2.	45 mm and 26.5 mm	10.0
3.	22.4 mm, 13.2 mm, 11.2 mm and 6.7 mm	5.0
4.	Fine aggregate	5.0

521.6 Rates

The contract unit rates for different sizes of coarse aggregate, fine aggregate and stone filler shall be payment in full for collecting, conveying and stacking or storing at the site including full compensation for:

i) all royalties, fees, rents where necessary;

ii) all leads and lifts; and

iii) all labour, tools, equipment and incidentals to complete the work to the specifications.

iv) All necessary testing of material, both initial, to approve the source, and regular control testing thereafter.

600

Concrete Pavement

601 DRY LEAN CEMENT CONCRETE SUB-BASE

601.1 Scope

601.1.1 The work shall consist of construction of dry lean concrete sub-base for cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross-sections shown on the drawings or as directed by the Engineer. The work shall include furnishing of all plant and equipment, materials and labour and performing all operations, in connection with the work, as approved by the Engineer.

601.1.2 The design parameters of Dry Lean Concrete (DLC) sub-base, viz., width, thickness, grade of concrete, details of joints, if any, etc. shall be as stipulated in the Contract drawings.

601.2 Materials

601.2.1 **Source of Materials :** The Contractor shall indicate to the Engineer the source of all materials with relevant test data to be used in the dry lean concrete work sufficiently in advance and the approval of the Engineer for the same shall be obtained at least 45 days before the scheduled commencement of the work in trail length. If the Contractor later proposes to obtain the materials from a different source, he shall notify the Engineer for his approval at least 45 days before such materials are to be used.

601.2.2 **Cement :** Any of the following types of cement may be used with prior approval of the Engineer:

S. No.	Type	Conforming to
i)	Ordinary Portland Cement 43 Grade	IS:8112
ii)	Portland Blast Furnace Slag Cement	IS:455
iii)	Portland Pozzolana Cement	IS:1489-Part I
iv)	Ordinary Portland Cement 53 Grade	IS:12269

Note:

1) Fly ash upto 20 percent by weight of Cement may be used in 53 Grade Cement. No fly ash shall be used in any other grade of Cement other than 53 Grade. The fly ash shall conform to IS:3812 (Part-I).

2) Site mixing of fly ash shall be permitted only after ensuring availability at site, uniform blending through a specific mechanical facility with automated process control like batch mix plant conforming to IS:4925 and IS:4926.

3) Mix design will be done as per IRC:SP:49. The OPC content shall not be less than 135 kg/cu.m in case of blending at site. The curing period may be suitably enhanced (by atleast about 2 days).

If the sub-grade is found to consist of soluble sulphates in a concentration more than 0.5 percent, cement used shall be sulphate resistant and shall conform to IS:6909.

Cement to be used may preferably be obtained in bulk form. It shall be stored in accordance with stipulations contained in Clause 1014 and shall be subjected to acceptance test prior to its immediate use.

601.2.3 Aggregates

601.2.3.1 Aggregates for lean concrete shall be natural material complying with IS:383. The aggregates shall not be alkali reactive. The limits of deleterious materials shall not exceed the requirements set out in IS:383. In case the Engineer considers that the aggregates are not free from dirt, the same may be washed and drained for at least 72 hours before batching, or as directed by the Engineer.

601.2.3.2 Coarse aggregates : Coarse aggregates shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated, very angular or splintery pieces. The crushed gravel/aggregate shall have atleast one fracture faces. The maximum size of the coarse aggregate shall be 31.5 mm. The coarse aggregate shall comply with Clause 602.2.4.2.

601.2.3.3 Fine aggregates : The fine aggregates shall consist of clean, natural sand or crushed stone sand or a combination of the two and shall conform to IS:383. Fine aggregate shall be free from soft particles, clay, shale, loam, cemented particles, mica, organic and other foreign matter. The fine aggregate shall comply with Clause 602.2.4.3. The fine aggregate shall not contain deleterious substances more than the following:

Clay lumps	1.0 percent
Coal and lignite	1.0 percent
Material passing IS Sieve No.75 micron	
i) Natural sand (Uncrushed)	3.0 percent
ii) Crushed sand	8.0 percent

601.2.3.4 The coarse and fine aggregates may be obtained in either of the following manner:

i) In separate nominal sizes of coarse and fine aggregates and mixed together intimately before use.

ii) Separately as 31.5 mm nominal, 25 mm nominal single size, 12.5 mm nominal size graded aggregates and fine aggregate of crushed stone dust or sand or a combination of these three. They shall be mixed together in prescribed proportion before use.

iii) Combined flakiness and elognation index shall not be more than 35 percent.

The material after blending shall conform to the grading as indicated in Table 600-1.

Table 600-1 Aggregate Gradation for Dry Lean Concrete

Sieve Designation	Percentage by weight passing the Sieve
31.5 mm	100
26.50 mm	90-95
19.0 mm	80-90
9.50 mm	55-75
4.75 mm	35-60
600.00 micron	10-35
75.00 micron	0-8

601.2.4 **Water :** Water used for mixing and curing of concrete shall be clean and free from injurious amounts of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS:456.

601.2.5 **Storage of materials :** All materials shall be stored in accordance with the provisions of Clause 1014 of these Specifications and other relevant IS Specifications. All efforts must be made to store the materials in proper places so as to prevent their deterioration or contamination by foreign matter and to ensure their satisfactory quality and fitness for use in the work. The storage place must also permit easy inspection, removal and storage of materials. All such materials even though stored in approved godowns must be subjected to acceptance test immediately prior to their use. The requirements of storage yard specified in Clause 602.2.9 shall also be applicable.

In case of aggregates, the storing place must be elevated from the ground atleast by 150 mm and should be a pucca paved platform i.e. cementitious treated GSB or soil or any other granular material or brick paving.

601.3 Proportioning of Materials for the Mix

601.3.1 The mix shall be proportioned with a maximum aggregate cement ratio of 15: 1. The water content shall be adjusted to the optimum as per Clause 601.3.2 for facilitating compaction by rolling. The strength and density requirements of concrete shall

be determined in accordance with Clause 601.6 by making trial mixes. Care should be taken to prevent one fraction of aggregate falling into the other fraction of the hopper of the feeding bin while loading the individual fraction of aggregates into the bins.

601.3.2 Moisture content : The right amount of water for the lean concrete in the main work shall be decided so as to ensure full compaction under rolling and shall be assessed at the time of rolling the trial length. Too much water will cause the lean concrete to be heaving up before the wheels and picked up on the wheels of the roller and too little will lead to inadequate compaction, a low in-situ strength and an open-textured surface.

The optimum water content shall be determined and demonstrated by rolling during trial length construction and the optimum moisture content and degree of compaction shall be got approved from Engineer. While laying in the main work, the lean concrete shall have a moisture content between the optimum and optimum +2 percent, keeping in view the effectiveness of compaction achieved and to compensate for evaporation losses.

601.3.3 Cement content : The minimum cement content in the lean concrete shall be 150 kg/cu.m of concrete. In case flyash is blended at site as part replacement of cement, the quantity of flyash shall not be more than 20 percent by weight of OPC cement and the content of OPC shall not be less than 135 kg/cu.m. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary by the Contractor at his own cost.

601.3.4 Concrete strength : The average compressive strength of each consecutive group of 5 cubes made in accordance with Clause 903.5.1.1 shall not be less than 10 MPa at 7 days. In addition, the minimum compressive strength of any individual cube shall not be less than 7.5 MPa at 7 days. The design mix complying with the above Clauses shall be got approved from the Engineer and demonstrated in the trial length construction.

601.4 Sub-grade

The sub-grade shall conform to the grades and cross-sections shown on the drawings and shall be uniformly compacted to the design strength in accordance with these Specifications. The dry lean concrete sub-base shall not be laid on sub-grade softened by rain after its final preparation; surface trenches and soft spots, if any, must be properly back-filled and compacted to avoid any weak or soft spot. As far as possible, the construction traffic shall be avoided on the prepared sub-grade. DLC shall not be laid directly on any sub-grade.

Dry Lean Concrete acting as sub-base to the Paving Quality Concrete (PQC) shall be laid only on a granular sub-base/drainage layer as per Table 400-1. A day before placing of the subbase/drainage layer, the sub-grade surface shall be given a fine spray of water and rolled with one or two passes of a smooth wheeled roller. If Engineer feels it necessary, another fine spray of water may be applied just before placing drainage layer. If the

subgrade CBR is less than 8 percent, the subgrade shall be stabilized with lime, cement or any other stabilizer accredited by IRC or by mechanical stabilization so as to raise the CBR to not less than 15 percent in the field.

601.5 Construction

601.5.1 General : The pace and programme of the Dry Lean Concrete (DLC) sub-base construction shall be matching suitably with the programme of construction of the PQC over it. The DLC sub-base shall be overlaid with PQC only after 7 days of sub-base construction.

601.5.2 Batching and mixing : The batching plant shall be capable of proportioning the materials by weight, each type of material being weighed separately in accordance with Clause 602.9.3.2. The cement from the bulk stock shall be weighed separately from the aggregates. The capacity of batching and mixing plant shall be at least 25 percent higher than the proposed capacity for the laying arrangements. The batching and mixing shall be carried out preferably in a forced action, central batching and mixing plant having necessary automatic controls to ensure accurate proportioning and mixing. Other types of mixing plant shall be permitted subject to demonstration of their satisfactory performance during the trial length. The type and capacity of the plant shall be got approved by the Engineer before commencement of the trial length. The weighing balances shall be calibrated by weighing with large weighing machine or in a weigh bridge. The accuracy of weighing scales of the batching plant shall be within ±2 percent in the case of aggregates and ±1 percent in the case of cement, fly ash, ground granulated slag and water.

The design features of Batching Plant should be such that the shifting operations of the plant will not take long time when they are to be shifted from place to place with the progress of the work.

601.5.3 Transporting : Plant mix lean concrete shall be discharged immediately from the mixer, transported directly to the point where it is to be laid and protected from the weather by covering the tipping trucks with tarpaulin during transit. The concrete shall be transported by tipping trucks, sufficient in number to ensure a continuous supply of material to feed the laying equipment to work at a uniform speed and in an uninterrupted manner. The lead of the batching plant to paving site shall be such that the travel time available from mixing to paving as specified in Clause 601.5.5.2 will be adhered to. Tipping truck shall not have old concrete sticking to it. Each tipping truck shall be washed with water jet before next loading as and where required after inspection.

601.5.4 Placing : Lean concrete shall be placed by a paver with electronic sensor on sub-base/base as per Clause 400. The equipment shall be capable of laying the material in one layer in an even manner without segregation, so that after completion the total thickness is as specified. The paving machine shall have high amplitude tamping bars to give good initial compaction to the sub-base. One day before placing of the dry

lean cement concrete sub-base, the surface of the untreated granular sub-base/drainage layer shall be given a fine spray of water and rolled with a smooth wheeled roller.

The laying of a two-lane road sub-base may preferably be done in full width. In case of unavoidable situation lane by lane laying may be done. Preferably the lean concrete shall be placed and compacted across the full width of the road, by constructing it in one go or in two lanes paved forward simultaneously. No joints shall normally be constructed in Dry Lean Concrete construction except in the following situations.

Transverse butt type joint shall be provided at the end of the construction in a day. Longitudinal construction joint shall be provided only when lane by lane construction is done or in case of multiple lane exceeding two-lane, where pavers of adequate width capable of paving in one go are not available. Transverse joints in PQC shall not be co-terminous with the construction butt type joint of DLC. It shall be staggered from the construction butt type joint in DLC by 800-1000 mm.

Longitudinal joint in DLC shall be similarly staggered by 300-400 mm from the longitudinal joint of PQC.

The DLC shall be laid in such a way that it is atleast 500 mm wider on each side than the proposed width including paved shoulders of PQC.

601.5.5 Compaction

601.5.5.1 The compaction shall be carried out immediately after the material is laid and levelled. In order to ensure thorough compaction, rolling shall be continued on the full width till there is no further visible movement under the roller and the surface is closed. The minimum dry density obtained shall be 98 percent of that achieved during the trial length construction vide Clause 601.7. The densities achieved at the edges i.e. 0.5 m from the edge shall not be less than 96 percent of that achieved during the trial construction vide Clause 601.7.

601.5.5.2 The spreading, compacting and finishing of the lean concrete shall be carried out as rapidly as possible and the operation shall be so arranged as to ensure that the time between the mixing of the first batch of concrete in any transverse section of the layer and the final finishing of the same shall not exceed 90 minutes when the temperature of concrete is between 25^0C and 30^0C, and 120 minutes if less than 25^0C. This period may be reviewed by the Engineer in the light of the results of the trial run but in no case shall it exceed 120 minutes. Work shall not proceed when the temperature of the concrete exceeds 30^0C. If necessary, chilled water or addition of ice may be resorted to for bringing down the temperature. It is desirable to stop concreting when the ambient temperature is above 35°C. After compaction has been completed, roller shall not stand on the compacted surface for the duration of the curing period except during commencement of next day's work near the location where work was terminated the previous day.

601.5.5.3 Double drum smooth-wheeled vibratory rollers of minimum 80 to 100 kN static weight are suitable for rolling dry lean concrete. In case any other roller is proposed, the same shall be got approved from the Engineer, after demonstrating its performance. The number of passes required to obtain maximum compaction depends on the thickness of the dry lean concrete, the compatibility of the mix and the weight and type of the roller used. In-Situ density in green concrete by sand replacement method shall be determined and it will not be less 98 percent of the density in the trial length. The requirement of number of rollers shall be determined from the scale of the work to be undertaken.

601.5.5.4 In addition to the number of passes required (4-6) for compaction there shall be a preliminary pass without vibration to bed the Dry Lean Concrete down and again a final pass without vibration to remove roller marks and to smoothen the surface.

Special care and attention shall be exercised during compaction near joints, kerbs, channels, side forms and around gullies and manholes. In case adequate compaction is not achieved by the roller at these locations, use of plate vibrators shall be made, if so directed by the Engineer.

601.5.5.5 The final lean concrete surface on completion of compaction and immediately before overlaying, shall be well closed, free from movement under roller and free from ridges, low spots, cracks, loose material, pot holes, ruts or other defects. The final surface shall be inspected immediately on completion and all loose, segregated or defective areas shall be corrected by using fresh lean concrete material laid and compacted as per Specifications. For repairing honeycombed/hungry surface, concrete with aggregates of size 10 mm and below shall be spread and compacted. It is necessary to check the level of the rolled surface for compliance. Any level/thickness deficiency should be corrected after applying concrete with aggregates of size 10 mm and below after roughening the surface. Similarly the surface regularity also should be checked with 3 m straight edge.

601.5.5.6 Segregation of concrete in the tipping trucks shall be controlled by moving the dumper back and forth while discharging the mix into the same or by any appropriate means. Even paving operation shall be such that the mix does not segregate.

601.5.6 **Joints :** Construction and longitudinal joints shall be provided as per the drawings.

At longitudinal or transverse construction joints, unless vertical forms are used, the edge of compacted material shall be cut back to a vertical plane where the correct thickness of the properly compacted material has been obtained.

601.5.7 **Curing :** As soon as the lean concrete surface is compacted, curing shall commence. One of the following two methods shall be adopted:

a) Where water is available, curing may be done by covering the surface by gunny bags/hessian, which shall be kept wet continuously for 7 days by sprinkling water.

b) Where water is scarce, one of the following may be used

i) The initial curing shall be done by spraying with white pigmented liquid curing compound conforming to ASTM-C 309-81. The curing compound shall be white pigmented or transparent type with water retention index of 90 percent when tested in accordance with BS:7542. Curing compound shall be sprayed immediately after rolling is completed. As soon as the curing compound has lost its tackiness, the surface shall be covered with wet hessian for four days.

ii) Wax-based white pigmented curing compound with water retention index of 90 percent shall be used to cure the dry lean concrete. The curing compound shall conform to BS:7542. The compound shall be applied uniformly with a mechanical sprayer and with a hood to protect the spray from the wind. The curing compound shall be applied over the entire exposed surface of the DLC, including sides and edges, at the rate of 0.2 liters/sq.m.

The first application, referred to as curing application shall be applied immediately after the final rolling of DLC is completed. As soon as the curing compound loses tackiness, the surface shall be covered with wet hessian for four days. The second application of curing compound also referred to as the debonding application, shall be applied 24 to 48 hours prior to the PQC placement. Any damaged DLC shall be corrected prior to the second application. Normally, the manufacturer's instructions shall be followed for its application. After the second applications, no polythese separation membrane may be required.

601.6 Trial Mixes

The Contractor shall make trial mixes of dry lean concrete with moisture contents like 5.0, 5.5, 6.0, 6.5 and 7.0 percent using cement content specified and the specified aggregate grading but without violating the requirement of aggregate-cement ratio specified in Clause 601.3.1. Optimum moisture and density shall be established by preparing cubes (150 mm x 150 mm) with varying moisture contents. Compaction of the mix shall be done in three layers with vibratory hammer fitted with a square or rectangular foot as described in Clause 903.5.1.1. After establishing the optimum moisture, a set of six cubes shall be cast at that moisture for the determination of compressive strength on the third and the seventh day. Trial mixes shall be repeated if the strength is not satisfactory either by increasing cement content or using higher grade of cement. After the mix design is approved, the Contractor shall construct a trial section in accordance with Clause 601.7.

If during the construction of the trial length, the optimum moisture content determined as above is found to be unsatisfactory, the Contractor may make suitable changes in the moisture content to achieve the satisfactory mix. The cube specimens prepared with the changed mix content should satisfy the strength requirement. Before production of the mix, natural moisture content of the aggregate should be determined on a day-to-day basis so that the moisture content could be adjusted. The mix finally designed should neither stick to the rollers nor become too dry resulting in ravelling of surface.

601.7 Trial Length

601.7.1 The trial length shall be constructed at least 14 days in advance of the proposed date of commencement of work. At least 30 days prior to the construction of the trial length, the Contractor shall submit for the Engineer's approval a "Method Statement" giving detailed description of the proposed materials, plant, equipment, mix proportions, and procedure for batching, mixing, laying, compaction and other construction procedures. The Engineer shall also approve the location and length of trial construction which shall be a minimum of 100 m length laid in two days and for full width of the pavement. The trial length shall contain the construction of at least one transverse construction joint involving hardened concrete and freshly laid D.L.C. sub-base. The construction of trial length shall be repeated till the Contractor proves his ability to satisfactorily construct the D.L.C. sub-base.

601.7.2 Trial mixes shall be prepared as per Clause 601.6 in order to determine and demonstrate the optimum moisture content which results in the maximum dry density of the mix compacted by the rolling equipment and the minimum cement content that is necessary to achieve the strength stipulated in the drawing.

601.7.3 After the construction of the trial length, the in-situ density of the freshly laid material shall be determined by sand replacement method with 200 mm dia density cone. Three density holes shall be made at locations equally spaced along a diagonal that bisects the trial length, average of these densities shall be determined. These main density holes shall not be made in the strip 500 mm from the edges. The average density obtained from the three samples collected shall be the reference density and is considered as 100 percent. The field density of regular work will be compared with this reference density in accordance with Clauses 601.5.5.1 and 903.5.1.2. Atleast three (evenly spread) cores of minimum 100 mm dia per km shall be cut to check segregation or any other deficiency like strength etc.

601.7.4 The hardened concrete shall be cut over 3 m width and reversed to inspect the bottom surface for any segregation taking place. The trial length shall be constructed after making necessary changes in the gradation of the mix to eliminate segregation of the

mix. The lower surface shall not have honey-combing and the aggregates shall not be held loosely at the edges.

601.7.5 The trial length shall be outside the main works and shall not be less than 100 min length; laid in two days. The main work shall not start until the trial length has been approved by the Engineer. After approval has been given, the materials, mix proportions, moisture content, mixing, laying, compaction plant and construction procedures shall not be changed without the approval of the Engineer.

601.8 Tolerances for Surface Regularity, Level, Thickness, Density and Strength

The tolerances for surface regularity, level, thickness, density and strength shall conform to the requirements given in Clause 903.5. Control of quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

601.9 Traffic

No heavy commercial vehicles like trucks and buses shall be permitted on the dry lean concrete sub-base after its construction.

601.10 Measurement for Payment

The unit of measurement for dry lean concrete pavement shall be in cubic metre of concrete placed, based on the net plan area for the specified thickness shown on the drawings or as directed by the Engineer.

601.11 Rate

The Contract unit rate payable for dry lean concrete sub-base shall be for carrying out the required operations including full compensation for all labour, materials and equipment, mixing, transport, placing, compacting, finishing, curing, rectification of defective surface testing and incidentals to complete the work as per Specifications, all royalties, fees, storage and rents where necessary and all leads and lifts.

602 CEMENT CONCRETE PAVEMENT

602.1 Scope

602.1.1 The work shall consist of construction of un-reinforced, dowel jointed, plain cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross sections shown on the drawings. The work shall include furnishing of all plant and equipment, materials and labour and performing all operations in connection with the work, as approved by the Engineer.

602.1.2 The design parameters, viz., thickness of pavement slab, grade of concrete, joint details etc. shall be as stipulated in the drawings.

602.2 Materials

602.2.1 **Source of materials :** The Contractor shall indicate to the Engineer the source of all materials to be used in the concrete work with relevant test data sufficiently in advance, and the approval of the Engineer for the same shall be obtained at least 45 days before the scheduled commencement of the work in trial length. If the Contractor subsequently proposes to obtain materials from a different source during the execution of main work, he shall notify the Engineer, with relevant test data, for his approval, at least 45 days before such materials are to be used.

602.2.2 **Cement :** Any of the following types of cement capable of achieving the design strength may be used with prior approval of the Engineer.

S.No.	Type	Conforming to
i)	Ordinary Portland Cement 43 Grade	IS:8112
ii)	Portlant Slag Cement	IS:455
iil)	Portland Pozzolana Cement	IS:1489-Part I
iv)	Ordinary Portland Cement 53 Grade	IS:12269

Note:

1) Fly ash upto 20 percent by weight of cement may be used in ordinary portland cement 53 Grade. No fly ash shall be used in any other grade of Cement other than 53 Grade. The fly ash shall conform to IS:3812 (Part I).

2) Ground Granulated Blast Furnance Slag (GGBFS) obtained by grinding granulated slag conforming to IS:12089. GGBFS shall not be used in any other grade of cement except 53 grade. The content of GGBFS shall be upto 50 percent by weight of Ordinary Portland Cement 53 grade.

3) Site mixing of fly ash and ground granulated slag shall be permitted only after ensuring availability of the equipments at site for uniform blending through a specific mechanized facility with automated process control like batch mix plants conforming to IS:4925 and IS:4926. Site mixing will not be allowed otherwise.

4) Mix design will be done as per IRC:44. The OPC content shall not be less than 310 kg/cu.m in case of blending at site. The curing period may be suitably enhanced by at least about 2 days.

5) The Portland Pozzolana Cement produced in factory shall not have fly ash content more than 25 percent. The Portland Pozzolana Cement produced in factory with fly ash content more than 25 percent shall not be used. Certificate from the manufacturer to this effect shall be procured before use.

If the soil around PQC has soluble salts like sulphates in excess of 0.5 percent, the cement used shall be sulphate resistant and shall conform to IS:12330.

Guidance may be taken from IRC:44 for ascertaining the compressive/flexural strength of cement concrete required to match with the prescribed design strength of concrete. Cement to be used may preferably be obtained in bulk form. If cement in paper bags is proposed to be used, there shall be bag-splitters with the facility to separate pieces of paper bags and dispose them off suitably. No paper pieces shall enter the concrete mix. Bulk cement shall be stored in accordance with Clause 1014. The cement shall be subjected to acceptance test just prior to its use.

602.2.3 Chemical Admixtures : Admixtures conforming to IS:9103 and IS:6925 shall be permitted to improve workability of the concrete or extension of setting time, on satisfactory evidence that they will not have any adverse effect on the properties of concrete with respect to strength, volume change, durability and have no deleterious effect on steel bars. The particulars of the admixture and the quantity to be used, must be furnished to the Engineer in advance to obtain his approval before use. Satisfactory performance of the admixtures should be proved both on the laboratory concrete trial mixes and in the trial length paving. If air entraining admixture is used, the total quantity of air in air-entrained concrete as a percentage of the volume of the mix shall be 5±1.5 percent for 31.5 mm nominal size aggregate.

602.2.3.1 Fibers : Fibers may be used subject to the provision in the design/approval by the Engineer to reduce the shrinkage cracking and post-cracking. The fibers may be steel fiber as per IRC:SP:46 or polymeric Synthetic Fibres within the following range of specifications:

- Effective Diameter 10 micron – 1.0 mm
- Length 6-48 mm

- Specific gravity — more than 1.0
- Suggested dosage — 0.6-2.0 kg/cu.m (0.2 -0.6 % by weight of cement in mix).

  Usage will be regulated as stipulated in IRC:44/IS:456 or any other specialist literature.
- Water absorption — less than 0.45 percent
- Melting point of this fiber shall not be less than 160°C.
- The aspect ratio generally varies from 200 to 2000.
- These synthetic fibers will have good alkali and UV light resistance.

When fibers are used, the mix shall be so designed that the slump at paving concrete is 30±15 mm site.

602.2.4 Aggregates

602.2.4.1 Aggregates for pavement concrete shall be natural material complying with IS:383 but with a Los Angeles Abrasion Test result not more than 35 percent. The limits of deleterious materials shall not exceed the requirements set out in Table 600-2.

The aggregates shall be free from chert, flint, chalcedony or other silica in a form that can react with the alkalies in the cement. In addition, the total chlorides content expressed as chloride ion content shall not exceed 0.06 percent by weight and the total sulphate content expressed as sulphuric anhydride (SO_3) shall not exceed 0.25 percent by weight. In case the Engineer considers that the aggregates are not free from dirt, the same may be washed and drained for atleast 72 hours before batching, as directed by the Engineer.

602.2.4.2 Coarse aggregates : Coarse aggregates shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated, very angular or splintery pieces. The maximum size of coarse aggregate shall not exceed 31.5 mm for pavement concrete. Continuously graded aggregates shall be used as per Table 600-1, No aggregate which has water absorption more than 2 percent shall be used in the concrete mix. The aggregates shall be tested for soundness in accordance with IS:2386 (Part-5). After 5 cycles of testing, the loss shall not be more than 12 percent if sodium sulphate solution is used or 18 percent if magnesium sulphate solution is used. The combined flakiness and alognation index of aggregate shall not be more than 35 percent.

Dumping and stacking of aggregates shall be done in an approved manner.

602.2.4.3 Fine aggregates : The fine aggregates shall consist of clean natural sand or crushed stone sand or a combination of the two and shall conform to IS:383. Fine aggregate shall be free from soft particles, clay, shale, loam, cemented particles, mica and organic and other foreign matter.

602.2.5 Water : Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS:456.

602.2.6 Mild steel bars for dowels and tie bars :

i) Dowel Bar shall be of plain mild steel conforming to IS:432 and will have yield stress of Fe-240.

ii) Tie bar shall be of TMT steel conforming to IS:1786 and will have yield stress of Fe-500.

Table 600-2 Permissible Limits of Deleterious Substances in Fine and Coarse Aggregates

Sl. No.	Deleterious Substance	Method of Test	Fine Aggregate Percentage by Weight, (Max)		Coarse Aggregate percentage by Weight (Max)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Uncrushed*	Crushed	Uncrushed*	Crushed
i)	Coal and lignite	IS:2386 (Part II) -1963	1.00	1.00	1.00	1.00
ii)	Clay mumps	do	1.00	1.00	1.00	1.00
iii)	Mateirals finer than 75 µ IS Sieve	IS:2386 (Part I) - 1963	3.00	8.00	3.00	3.00
iv)	Soft fragments	IS:2386 (part II) - 1963	-	-	3.00	-
v)	Shale	IS:2386 (part II) - 1963	1.00	-	-	-
vi)	Total of percentages of all deleterious materials (except mica) including Sl No. (i) to (v) for col 4, 6 and 7 and Sl No. (i) and (ii) for col 5 only	-	5.00	2.00	5.00	5.00

* Crushed aggregate at least one face fractured

Note: The presence of mica in the fine aggregate has been found to reduce considerably the durability and compressive strength of concrete and further investigations are underway to determine the extent of the deleterious effect of mica. It is advisable, therefore, to investigate the mica content of fine aggregate and make suitable allowances for the possible reduction in the strength of concrete or mortar; in cases where the stretch of the project road passes through micacious belt.

602.2.7 Premoulded joint filler : Joint filler board for expansion joints shall be used only at abutting structures like bridges and shall be of 20-25 mm thickness within a tolerance of ± 1.5 mm and of a firm compressible material and complying with the requirements of IS:1838, or BS:2630 "Preformed Joint Filler". It shall be 25 mm less in depth than the thickness of the slab within a tolerance of ± 3 mm and provided to the full width between the side forms. It shall be in suitable lengths which shall not be less than one lane width. Holes to accommodate dowel bars shall be accurately bored or punched out to give a sliding fit on the dowel bars.

602.2.8 Joint sealing compound : The joint sealing compound shall be of hot poured, elastomeric type or cold polysulphide/polyurethene/silicon type having flexibility, resistance to age hardening and durability as per IRC:57. Manufacturer's certificate shall be produced by the Contractor for establishing that the sealant is not more than six months old and stating that the sealant complies with the relevant standard as in Clause 602.2.8. The samples shall meet the requirements as mentioned in IRC:57. Hot applied sealant shall be as per IS:1834.

Cold poured sealant shall be as under :

i)	Polysulphide	BS:5212, IS:11433
ii)	Polyurethene	BS:5212
iii)	Silicon	ASTM 5893-96

602.2.9 Storage of materials : All materials shall be stored in accordance with the provisions of Clause 1014 of the Specifications and other relevant IS Specifications. All efforts must be made to store the materials in proper places so as to prevent their deterioration or contamination by foreign matter and to ensure their satisfactory quality and fitness for the work. The platform where aggregates are stock piled shall be on a levelled platform elevated from the ground atleast by 150 mm. This platform will be a pucca paved platform. The area shall have slope and drain to drain off rain water. The storage space must also permit easy inspection, removal and storage of the materials. Aggregates of different sizes shall be stored in partitioned stack-yards. All such materials even though stored in approved godowns must be subjected to acceptance test as per Clause 903 of these Specifications immediately prior to their use.

602.3 Proportioning of Concrete

602.3.1 After approval by the Engineer of all the materials to be used in the concrete, the Contractor shall submit the mix design based on weighed proportions of all ingredients for the approval of the Engineer. The mix design shall be submitted at least 30 days prior to the paving of trial length and the design shall be based on laboratory trial mixes using the approved materials and methods as per IRC:44 or IS:10262 (Recommended Guidelines for Mix Design). The target mean strength for the design mix shall be determined as

indicated in Clause 602.3.3.1. The mix design shall be based on the flexural strength of concrete.

602.3.2 Cement content : When Ordinary Portland Cement (OPC) is used the quantity of cement shall not be less than 360 kg/cu.m. In case fly ash grade I (as per IS:3812) is blended at site as part replacement of cement, the quantity of fly ash shall be upto 20 percent by weight of cement and the quantity of OPC in such a blend shall not be less than 310 kg/cu.m. The minimum of OPC content in case ground granulated portland blast furnace is used, shall also not be less than 310 kg/m^3. If this minimum cement content is not sufficient to produce concrete of the specified strength, it shall be increased as necessary by the Contractor at his own cost.

602.3.3 Concrete strength

602.3.3.1 The characteristic flexural strength of concrete shall not be less than 4.5 MPa (M 40 Grade). Target mean flexural strength for mix design shall be more than 4.5 MPa + 1.65*s, where s is standard deviation of flexural strength derived by conducting test on minimum 30 beams. While designing the mix in the laboratory, correlation between flexural and compressive strengths of concrete shall be established on the basis of at least thirty tests on samples. However, quality control in the field shall be exercised on the basis of flexural strength. It may, however, be ensured that the materials and mix proportions remain substantially unaltered during the daily concrete production. The water content shall be the minimum required to provide the agreed workability for full compaction of the concrete to the required density as determined by the trial mixes or as approved by the Engineer and the maximum free water cement ratio shall be 0.45 when only OPC is used and 0.50 when blended cement (Portland Pozzolana Cement or Portland Slag Cement or OPC blended with fly ash or Ground Granulated Blast Furnance Slag at site) is used.

602.3.3.2 The ratio between the 7 and 28 day strength shall be established for the mix to be used in the slab in advance, by testing pairs of beams and cubes at each stage on at least six batches of trial mix. The average strength of the 7 day cured specimens shall be divided by the average strength of the 28 day specimens for each batch, and the ratio “R’ shall be determined. The ratio ‘R’ shall be expressed to three decimal places.

If during the construction of the trial length or during some normal working, the average value of any four consecutive 7 day test results falls below the required 7 day strength as derived from the value of ‘R’ then the cement content of the concrete shall, without extra payment, be increased by 5 percent by weight or by an amount agreed by the Engineer. The increased cement content shall be maintained at least until the four corresponding 28 day strengths have been assessed for in conformity with the requirements as per Clause 602.3.1. Whenever the cement content is increased, the concrete mix shall be adjusted to maintain the required workability.

602.3.4 Workability

602.3.4.1 The workability of the concrete at the point of placing shall be adequate for the concrete to be fully compacted and finished without undue flow. The optimum workability for the mix to suit the paving plant being used shall be determined by the Contractor and approved by the Engineer. The control of workability in the field shall be exercised by the slump test as per IS:1199.

602.3.4.2 The workability requirement at the batching and mixing plant and paving site shall be established by slump tests carried during trial paving. These requirements shall be established from season to season and also when the lead from batching and mixing plant site to the paving site changes. The workability shall be established for the type of paving equipment available. A slump value in the range of 30 ± 15 mm is reasonable for paving works but this may be modified depending upon the site requirement and got approved by the Engineer. These tests shall be carried out on every truck/dumper at batching and mixing plant site and paving site initially when the work commences but subsequently the frequency can be reduced to alternate trucks or as per the instructions of the Engineer.

602.3.5 Design mix

602.3.5.1 The Contractor shall carry out laboratory trials of design mix with the materials from the approved sources to be used. Trial mixes shall be made in presence of the Engineer or his representative and the design mix shall be subject to the approval of the Engineer. They shall be repeated, if necessary, until the proportions, that will produce a concrete which complies in all respects with these Specification, and conform to the requirements of the design/drawings.

602.3.5.2 The proportions determined as a result of the laboratory trial mixes may be adjusted, if necessary, during the construction of the trial length. Thereafter, neither the materials nor the mix proportions shall be varied in any way except with the written approval of the Engineer.

602.3.5.3 Any change in the source of materials or mix proportions proposed by the Contractor during the course of work shall be assessed by making laboratory trial mixes and the construction of a further trial length unless approval is given by the Engineer for minor adjustments like compensation for moisture content in aggregates or minor fluctuations in the grading of aggregate.

602.4 Sub-base

The cement concrete pavement shall be laid over the DLC sub-base constructed in accordance with the relevant drawings and Specifications contained in Clause 601. The DLC will be laid on GSB as per Clause 400. If the DLC sub-base is found damaged at

some places or it has cracks wider than 10 mm, it shall be repaired with fine cement concrete or bituminous concrete before laying separation membrane layer. Prior to laying of concrete it shall be ensured that the separation membrane as per Clause 602.5 is placed in position and the same is clean of dirt or other extraneous materials and free from any damage.

Mixing and Granular sub base material or in a pug mill shall be done mechanically in a separate yard through motor grader to ensure uniform mixing. Mix-in-place method will normally not be allowed except in exceptional situation, with the approval of the Engineer. The DLC sub-base/WMM/base (treated with cement etc.) of grading specified in the Contract shall be spread on the prepared sub-grade with the help of a motor grader of adequate capacity, its blade having hydraulic controls suitable for initial adjustment and for maintaining the required slope and grade during the operation or other means as approved by the Engineer. The surface levels and surface regularity shall be as per provision contained in IRC:SP:16.

Emerging literature suggests alternative for both DLC and separation membrane. Due to lack of indigeneous experience available, the same are not provided in these Specifications. It is, however, felt that these alternative Specifications may be tried atleast on experimental basis, by consulting specialist literature. Some of such possible alternatives are laying PQC on base course like WMM, soil treated with cement (cementitious material) as instead of DLC. Design of PQC in such cases, shall include checking against pumping/erosion besides fatique. Two courses of wax based curing compound or two coats of bitumen or 5 mm thick non-woven geo-fabric sheet, instead of polythene film are some of the emerging alternatives for membrane.

DLC sub-base shall be laid with paver and not with grader.

602.5 Separation Membrane

A separation membrane shall be used between the concrete slab and the sub-base. Separation membrane shall be impermeable PVC sheet 125 micron thick transparent or white in colour laid flat with minimum creases. Before placing the separation membrane, the sub-base shall be swept clean of all the extraneous materials using air compressor. Wherever overlap of plastic sheets is necessary, the same shall be at least 300 mm and any damaged sheathing shall be replaced at the Contractor’s cost. The separation membrane may be nailed to the lower layer with concrete nails.

602.6 Joints

602.6.1 The locations and type of joints shall be as shown in the drawing. Joints shall be constructed depending upon their functional requirement. The location of the joints should be transferred accurately at the site and mechanical saw cutting of joints done as per stipulated dimensions. It shall be ensured that the required depth of cut is made from

edge-to-edge of the pavement. Transverse and longitudinal joints in the pavement (PQC) and DLC sub-base shall be staggered so that they are not coincident vertically and are at least 800 to 1000 mm and 300 to 400 mm apart respectively. Sawing of joints shall be carried out with diamond studded blades soon after the concrete has hardened to take the load of the sawing machine and personnel without damaging the texture of the pavement.

Sawing operation could start as early as 5-6 hours after laying of PQC but not later than 18 to 20 hours depending upon the ambient temperature, wind velocity and relative humidity and required maturity of concrete achieved for this purpose.

When the kerb is cast integrally with the main pavement slab, the joint cutting shall also be extended to the kerb.

When on instructions of the Engineer, the use of maturity meter is specified, sawing should not be initiated when the compressive strength of the concrete is less than 2 MPa and should be completed before it attains the compressive strength of 7 MPa.

602.6.2 Transverse joints

602.6.2.1 Transverse joints shall be contraction and expansion joints constructed at the spacing described in the drawings. Transverse joints shall be straight within the following tolerances along the intended line of joints which is the straight line transverse to the longitudinal axis of the carriageway at the position proposed by the Contractor and agreed to by the Engineer, except at road junctions or roundabouts where the position shall be as described in the drawings:

- i) Deviations of the filler board in the case of expansion joints from the intended line of the joint shall not be greater than ± 10 mm.
- ii) The best fit straight line through the joint grooves as constructed shall be not more than 25 mm from the intended line of the joint.
- iii) Deviations of the joint groove from the best fit straight line of the joint shall not be greater than 10 mm.
- iv) Transverse joints on each side of the longitudinal joint shall be in line with each other and of the same type and width. Transverse joints shall have a sealing groove which shall be sealed in compliance with Clause 602.11.

602.6.2.2 **Contraction joints** : The contraction joints shall be placed transversely at pre-specified locations as per drawings/design using dowel bars. These joints shall be cut as soon as the concrete has undergone initial hardening and is hard enough to take the load of joint sawing machine without causing damage to the slab.

Contraction joints shall consist of a mechanical sawn joint groove, 3 to 5 mm wide and ¼th to ⅓rd depth of the slab ± 5 mm or as stipulated in the drawings and dowel bars complying with Clause 602.6.5.

Contraction joint shall be widened subsequently accommodate the sealant as per Clause 602.11, to dimensions shown on drawings or as per IRC:57.

602.6.2.3 Expansion joints : The expansion joints shall consist of a joint filler board complying with Clause 602.2.7 and dowel bars complying with Clause 602.6.5 and as detailed in the drawings. The filler board shall be positioned vertically with the prefabricated joint assemblies along the line of the joint within the tolerances given in Clause 602.6.2.1 and at such depth below the surface as will not impede the passage of the finishing straight edges or oscillating beams of the paving machines. The adjacent slabs shall be completely separated from each other by providing joint filler board. Space around the dowel bars, between the sub-base and the filler board shall be packed with a suitable compressible material to block the flow of cement slurry.

602.6.3 Transverse construction joint : Transverse construction joint shall be placed whenever concreting is completed after a day's work or is suspended for more than 30 minutes. These joints shall be provided at location of constructing joints using dowel bars. The construction joints may preferebly coincide with the pre-specified location of contruction joints by properly planning the day to day concreting work of PQC. The joint shall be made butt type. At all construction joints, steel bulk heads shall be used to retain the concrete while the surface is finished. The surface of the concrete laid subsequently shall conform to the grade and cross sections of the previously laid pavement. When positioning of bulk head/stop-end is not possible, concreting to an additional 1 or 2 m length may be carried out to enable the movement of joint cutting machine so that joint grooves may be cut and the extra 1 or 2 m length is cut out and removed subsequently after concrete has hardened.

Like contraction joint, the construction joint shall also be widened to dimensions shown on drawing or as per IRC:57, not before 14 days curing of PQC.

602.6.4 Longitudinal joint

602.6.4.1 The longitudinal joints shall be saw cut as per details of the joints shown in the drawing or as per dimensions given in IRC:57. The groove may be cut after the final set of the concrete. Joints should be sawn to at least ⅓rd the depth of the slab ±5 mm as indicated in the drawing.

602.6.4.2 Tie bars shall be provided at the longitudinal joints as per dimensions and spacing shown in the drawing and in accordance with Clause 602.6.6.

Logitudinal joint shall also be widened to dimensions shown on drawing or as per IRC:57, not before 14 days curing of PQC.

602.6.5 Dowel bars

602.6.5.1 Dowel bars shall be mild steel rounds in accordance with Clause 602.2.6 with details/dimensions as indicated in the drawings and free from oil, dirt, loose rust or scale. They shall be straight, free of irregularities and burring restricting slippage in the concrete. The sliding ends shall be sawn or cropped cleanly with no protrusions outside the normal diameter of the bar. To remove any protrusions, the ends of the dowel bars shall be suitably grounded. The dowel bar shall be supported on cradles/dowel chairs in pre-fabricated joint assemblies positioned prior to the construction of the slabs or mechanically inserted with vibration into the plastic concrete by a method which ensures correct placement of the bars besides full re-compaction of the concrete around the dowel bars. Modern slip form pavers are equipped with automatic dowel bar inserter (DBI).

602.6.5.2 Unless shown otherwise on the drawings, dowel bars shall be positioned at mid depth of the slab within a tolerance of ±20 mm, and centered equally about intended lines of the joint within a tolerance of ±25 mm. They shall be aligned parallel to the finished surface of the slab and to the centre line of the carriageway and to each other within tolerances given hereunder, the compliance of which shall be checked as per Clause 602.10.7.

i) For bars supported on cradles prior to the laying of the slab:

   a) All bars in a joint shall be within ±3 mm per 300 mm length of bar

   b) 2/3rd of the number of bars shall be within ±2 mm per 300 mm length of bar

   c) No bar shall differ in alignment from an adjoining bar by more than 3 mm per 300 mm length of bar in either the horizontal or vertical plane

   d) Cradles supporting dowel bar shall not extend across the line of joint i.e. no steel bar of the cradle assembly shall be continuous across the joint.

ii) For all bars inserted after laying of the slab the tolerance for alignment may be twice as indicated in (i) above.

602.6.5.3 Dowel bars, supported on cradles in assemblies, when subject to a load of 110 N applied at either end and in either the vertical or horizontal direction (upwards and downwards and both directions horizontally) shall conform to be within the limits given in Clause 602.6.5.2.

602.6.5.4 The assembly of dowel bars and supporting cradles, including the joint filler board in the case of expansion joints, shall have the following degree of rigidity when fixed in position:-

i) For expansion joints, the deflection of the top edge of the filler board shall be not greater than 13 mm, when a load of 1.3 kN is applied perpendicular to the vertical face of the joint filler board and distributed over a length of 600 mm by means of a bar or timber packing, at mid depth and midway between individual fixings, or 300 mm from either end of any length of filler board, if a continuous fixing is used. The residual deflection after load shall be not more than 3 mm.

ii) The joint assembly fixing to sub-base shall not fail under the 1.3 kN load applied for testing the rigidity of the assembly but shall fail before the load reaches 2.4 kN.

iii) The fixings for contraction joint shall not fail under 1.3 kN load and shall fail before the load reaches 2.6 kN when applied over a length of 600 mm by means of a bar or timber packing placed as near to the level of the line of fixings as practicable.

iv) Fixings shall be deemed to fail when there is displacement of the assemblies by more than 3 mm with any form of fixing, under the test load. The displacement shall be measured at the nearest part of the assembly to the centre of the bar or timber packing.

602.6.5.5 Dowel bars in the contraction joints, construction joints and expansion joints shall be covered by a thin plastic sheath. The sheath shall be not more than 125 micron thick and shall be tightly fitted on the bar for at least two-thirds of the length from one end for dowel bars in contraction joints or half the length plus 50 mm for expansion joints. The sheathed bar shall comply with the following pull-out tests:

i) Four bars shall be taken at random from stock and without any special preparation shall be covered by sheaths as required in this Clause. The ends of the dowel bars which have been sheathed shall be cast centrally into concrete specimens 150 mm x 150 mm x 600 mm, made of the same mix proportions to be used in the pavement, but with a maximum nominal aggregate size of 20 mm and cured in accordance with IS:516. At 7 days a tensile load shall be applied to achieve a movement of the bar of at least 0.25 mm. The average bond stress to achieve this movement shall not be greater than 0.14 MPa.

602.6.5.6 For expansion joints, a closely fitting cap 100 mm long consisting of waterproofed cardboard or an approved synthetic material like PVC or GI pipe shall be placed over the sheathed end of each dowel bar. An expansion space (about 25 mm) at least equal in length to the thickness of the joint filler board shall be formed between the

end of the cap and the end of the dowel bar by using compressible sponge. To block the entry of cement slurry between dowel and cap it shall be taped.

602.6.6 Tie bars

602.6.6.1 Tie bars in longitudinal joints shall be deformed steel bars of strength 500 MPa complying with IS:1786 and in accordance with the requirements given in this Clause. The bars shall be free from oil, dirt, loose rust and scale.

602.6.6.2 Tie bars projecting across the longitudinal joint shall be protected from corrosion for 75 mm on each side of the joint by a protective coating of bituminous paint with the approval of the Engineer. The coating shall be dry when the tie bars are used. In the case of coastal region, tie bars shall be epoxy coated as per IS:13620.

602.6.6.3 Tie bars in longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab. Alternatively, tie bars at longitudinal joints may be mechanically or manually inserted into the plastic concrete from above by vibration using a method which ensures correct placements of the bars and recompaction of the concrete around the tie bars. The modern slip form pavers are equipped with automatic tie bar inserter (TBI).

602.6.6.4 Tie bars shall be positioned to remain within the upper middle third of the slab depth as indicated in the drawings and approximately parallel to the surface and approximately perpendicular to the line of the joint, with the centre of each bar on the intended line of the joints within a tolerance of ±50 mm, and with a minimum cover of 30 mm below the joint groove.

602.7 Weather and Seasonal Limitations

602.7.1 Concreting during monsoon months : Concreting should be avoided during rainy season. However, when concrete is being placed during monsoon months and when it may be expected to rain, sufficient supply of tarpaulin or other waterproof cloth shall be provided along the line of the work. Any time when it rains, all freshly laid concrete which had not been covered for curing purposes shall be adequately protected. Any concrete damaged by rain shall be removed and replaced. If the damage is limited to texture, it shall be retextured in accordance with the directions of the Engineer.

602.7.2 Temperature limitation

No concreting shall be done when the concrete temperature is above 30°C. Besides, in adverse conditions like high temperature, low relative humidity, excessive wind velocity, imminence of rains etc., tents on mobile trusses may be provided over the freshly laid concrete for a minimum period of 3 hours as directed by the Engineer. The temperature of the concrete mix on reaching the paving site shall not be more than 30°C. To bring down

the temperature, if necessary, chilled water or ice flakes should be made use of. When the ambient temperature is more than 35^0C, no concreting shall be permitted.

No concreting shall be done when the concrete temperature is below 5^0C and the temperature is further falling.

602.8 Side Forms, Rails and Guidewires

602.8.1 Side forms and rails : These shall be provided in case of fixed form paving. All side forms shall be of mild steel of depth equal to the thickness of pavement or slightly less to accommodate the surface regularity of the sub-base. The forms can be placed in series of steel packing plates or shims to take care of irregularity of sub-base. They shall be sufficiently robust and rigid to support the weight and pressure caused by a paving equipment. Side forms for use with wheeled paving machines shall incorporate metal rails firmly fixed at a constant height below the top of the forms. The forms and rails shall be firmly secured in position by not less than 3 stakes/pins for every 3 m length so as to prevent movement in any direction. Forms and rails shall be straight within a tolerance of 3 mm in 3 m and when in place shall not settle in excess of 1.5 mm in 3 m while paving is being done. Forms shall be cleaned and oiled immediately before each use. The forms shall be bedded on a continuous bed of low moisture content lean cement mortar or concrete and set to the line and levels shown on the drawings within tolerances ±10 mm and ±3 mm respectively. The bedding shall not extend under the slab and there shall be no vertical step between adjacent forms of more than 3 mm. The forms shall be got inspected by the Engineer for his approval before 12 hours on the day before the construction of the slab and shall not be removed until at least 12 hours afterwards.

602.8.2 At all times sufficient forms shall be used and set to the required alignment for at least 300 m length of pavement immediately in advance of the paving operations, or the anticipated length of pavement to be laid within the next 24 hours whichever is more.

602.8.3 Use of guidewires

602.8.3.1 Where slip form paving is proposed, a guidewire shall be provided along both sides of the slab. Each guidewire shall be at a constant height above and parallel to the required edges of the slab as described in the contract/drawing within a vertical tolerance of ±3 mm. Additionally, one of the wires shall be kept at a constant horizontal distance from the required edge of the pavement as indicated in the contract drawing within a lateral tolerance of ±10 mm.

602.8.3.2 The guidewires shall be supported on stakes not more than 6 m apart by connectors capable of fine horizontal and vertical adjustment. The guidewire shall be tensioned on the stakes so that a 500 gm weight shall produce a deflection of not more than 20 mm when suspended at the mid point between any pair of stakes. The ends of the

guidewires shall be anchored to fixing point or winch and not on the stakes. On the curves, the stakes shall be fixed at not more than 3 m centre-to-centre.

602.8.3.3 The stakes shall be positioned and hammered into the ground and the connectors will be maintained at their correct height and alignment from 12 hours on the day before concreting takes place until 12 hours after finishing of the concrete.

The guidewire shall be erected and tensioned on the connectors at any section for at least 2 hours before concreting that section.

602.8.3.4 The Contractor shall submit to the Engineer for his approval of line and level, the stakes and connectors which are ready for use in the length of road to be constructed by 12 hours on the working day before the day of construction of slab. Any deficiencies noted by the Engineer shall be rectified by the Contractor who shall then re-apply for approval of the affected stakes. Work shall not proceed until the Engineer has given his approval. It shall be ensured that the stakes and guidewires are not affected by the construction equipment when concreting is in progress.

602.9 Construction

602.9.1 General : A systems approach may be adopted for construction of the pavement, and the Method Statement for carrying out the work, detailing all the activities, indication of time-cycle, equipment, personnel etc., shall be got approved from the Engineer before the commencement of the work. This shall include the type, capacity and make of the batching and mixing plant besides the hauling arrangement and paving equipment. The capacity of paving equipment, batching plant as well as all the ancillary equipment shall be adequate for a paving rate of atleast 500 m in one day. The desirable paving speed of slipform pavers is 1.0 m per minute, but it shall not be less than 0.6 m per minute average. The concreting should proceed continuously without stop & start.

602.9.2 Batching and mixing : Batching and mixing of the concrete shall be done at a central batching and mixing plant with automatic controls, located at a suitable place which takes into account sufficient space for stockpiling of cement, aggregates and stationary water tanks. This shall be, however, situated at an approved distance, duly considering the properties of the mix and the transporting arrangements available with the Contractor.

The dose of plasticizer/super plasticizer shall be added in the end of input of all ingredients i.e. when cement, aggregate, fly ash and water etc. have been thoroughly mixed. Proper dispersal of plasticizer/super plasticizer and air entraining agent (when used) shall be ensured.

Tipping trucks shall be washed at a regular frequency as prescribed by the Engineer to ensure that no left-over mix of previous loading remains stuck. Desirably each tipping truck shall be washed with water jet before next loading.

602.9.3 Equipment for proportioning of materials and paving

602.9.3.1 Proportioning of materials shall be done in the batching plant by weight, each type of material being weighed separately. The cement from the bulk stock may be weighed separately from the aggregates. Water shall be measured by volume. Specified percentage of plasticizer in volume will be added by weight of cement. Wherever properly graded aggregate of uniform quality cannot be maintained as envisaged in the mix design, the grading of aggregates shall be controlled by appropriate blending techniques. The capacity of batching and mixing plant shall be at least 25 percent higher than the proposed capacity of the laying/paving equipment.

602.9.3.2 Batching plant and equipment :

1) **General :** The batching plant shall include minimum four bins, weighing hoppers, and scales for the fine aggregates and for each size of coarse aggregate. If cement is used in bulk, a separate scale for cement shall be included. The weighing hoppers shall be properly sealed and vented to preclude dust during operation. Approved safety devices shall be provided and maintained for the protection of all personnel engaged in plant operaion, inspection and testing. The batch plant shall be equipped with a suitable non-resettable batch counter which will correctly indicate the number of batches proportioned.

2) **Bins and hoppers :** Bins with minimum number of four adequate separate compartments shall be provided in the batching plant.

3) **Automatic weighing devices :** Batching plant shall be equipped to proportion aggregates and bulk cement by means of automatic weighing devices using load cells.

4) **Mixer :** Mixers shall be pan type, reversible type or any other mixer capable of combining the aggregates, cement, and water into a thoroughly mixed and uniform mass within the specified mixing period, and of discharging the mix, without segregation. Each stationary mixer shall be equipped with an approved timing device which will automatically lock the discharge lever when the drum has been charged and release it at the end of the mixing period. The device shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the mixer may be used for the balance of the day while it is being repaired, provided that each batch is mixed in 90 seconds or as per the manufacturer's recommendation. The mixer shall be equipped with a suitable non-resettable batch counter which shall correctly indicate the number of batches mixed.

The mixers shall be cleaned at suitable intervals. The pic-kup and throw-over blades in the drum or drums shall be repaired or replaced when they are worn down 20 mm or more. The Contractor shall (1) have available at the job site a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth, or (2) provide permanent marks on blade to show points of 20 mm wear from new conditions. Drilled holes of 5 mm diameter near each end and at midpoint of each blade are recommended. Batching Plant shall be calibrated in the beginning and thereafter at suitable interval not exceeding 1 month.

5) **Control cabin :** An air-conditioned centralized computer control cabin shall be provided for automatic operation of the equipment.

602.9.3.3 Paving equipment : The concrete shall be placed with an approved fixed form or slip form paver with independent units designed to (i) spread, (ii) consolidate, screed and flat-finish, (iii) texture and cure the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary and so as to provide a dense and homogeneous pavement in conformity with the plans and Specifications. The paver shall be equipped with electronic sensor controls to control the line and grade from either or both sides of the machine.

Vibrators shall operate at a frequency of 8000-10000 impulses per minute under load at a maximum spacing of 600 mm. The variable vibration setting shall be provided in the machine.

602.9.3.4 Concrete saw : The Contractor shall provide adequate number of concrete saws with sufficient number of diamond-edge saw blades. The saw machine shall be either electric or petrol/diesel driven type. A water tank with flexible hoses and pump shall be made available in this activity on priority basis. The Contractor shall have at least one standby saw in good working condition. The concreting work shall not commence if the saws are not in working condition.

602.9.4 Hauling and placing of concrete

602.9.4.1 Freshly mixed concrete from the central batching and mixing plant shall be transported to the paver site by means of tipping trucks of sufficient capacity and approved design in sufficient numbers to ensure a constant supply of concrete. Covers shall be used for protection of concrete against the weather. While loading the concrete trucks shall be moved back and forth under the discharge chute to prevent segregation. The tipping trucks shall be capable of maintaining the mixed concrete in a homogeneous state and discharging the same without segregation and loss of cement slurry. The feeding to the paver is to be regulated in such a way that the paving is done in an uninterrupted manner with a uniform speed throughout the day's work.

602.9.4.2 Placing of concrete

Concrete mixed in central mixing plant shall be transported to the site without delay and the concrete which, in the opinion of the Engineer has been mixed too long before laying will be rejected and shall be removed from the site.

The total time taken from the addition of the water to the mix, until the completion of the surface finishing and texturing shall not exceed 120 minutes when concrete temperature is less than 25°C and 90 minutes when the concrete temperature is between 25°C and 30°C. Tipping trucks delivering concrete shall normally not run on plastic sheathing nor shall they run on completed slabs until after 28 days of placing the concrete.

The placing of concrete in front of the PQC paver should preferably be from the side placer to avoid damage to DLC by concrete tipping trucks. In case of unavoidable situation, truck supplying PQC concrete to the paver may be allowed to ply on the DLC with the approval of the Engineer. The paver shall be capable of paving the carriageway as shown in the drawings, in a single pass and lift. Equipments or accessory to support the edges of conceret by means of steel plates shall be maintained in position by screwed jacks.

602.9.4.3 Where fixed form pavers are to be used, forms shall be fixed in advance as per Clause 602.8. Before any paving is done, the site shall be shown to the Engineer, in order to verify the arrangement for paving besides placing of dowels, tie-bars etc., as per the relevant Clauses of these Specifications. The mixing and placing of concrete shall progress only at such a rate as to permit proper finishing, protecting and curing of the concrete in the pavement.

602.9.4.4 In all cases, the temperature of the concrete shall be measured at the point of discharge from the delivery vehicle.

602.9.4.5 The addition of water to the surface of the concrete to facilitate the finishing operations will not be permitted except with the approval of the Engineer when it shall be applied as a mist by means of approved equipment.

602.9.4.6 If considered necessary by the Engineer, the paving machines shall be provided with approved covers to protect the surface of the slab under construction from direct sunlight and rain or hot wind.

602.9.4.7 While the concrete is still plastic, its surface shall be textured by brush or tines as per the instructions of the Engineer in compliance with Clause 602.9.8. The surface and edges of the slab shall be cured by the application of a sprayed liquid curing membrane in compliance with Clause 602.9.9. After the surface texturing, but before the curing compound is applied, the concrete slab shall be marked with the chainage at every 100 m interval by embossing.

602.9.4.8 As soon as the side forms are removed, edges of the slabs shall be corrected wherever irregularities have occurred by using fine concrete composed of one part of cement to 3 parts of aggregate [1:1:2, cement : sand : coarse agg (10 mm down)] and fine aggregates under the supervision of the Engineer.

602.9.4.9 If the requirement of Clause 902.4. for surface regularity fails to be achieved on two consecutive working days, then normal working shall cease until the cause of the excessive irregularity has been identified and remedied.

602.9.5 Construction by fixed form paver

602.9.5.1 The fixed form paving train shall consist of separate powered machines which spread, compact and finish the concrete in a continuous operation.

602.9.5.2 The concrete shall be discharged without segregation into a hopper spreader which is equipped with means for controlling its rate of deposition on to the sub-base. The spreader shall be operated to strike off concrete upto a level requiring a small amount of cutting down by the distributor of the spreader. The distributor of spreader shall strike off the concrete to the surcharge adequate to ensure that the vibratory compactor thoroughly compacts the layer. If necessary, poker vibrators shall be used adjacent to the side forms and edges of the previously constructed slab. The vibratory compactor shall be set to strike off the surface slightly high so that it is cut down to the required level by the oscillating beam. The machine shall be capable of being rapidly adjusted for changes in average and differential surcharge necessitated by changes in slab thickness or crossfall. The final finisher shall be able to finish the surface to the required level and smoothness as specified, care being taken to avoid bringing up of excessive mortar to the surface by over working.

602.9.6 Construction by slip form paver

602.9.6.1 The slip form paving train shall consist of power machine which spreads, compacts and finishes the concrete in a continuous operation. The slip form paving machine shall compact the concrete by internal vibration and shape it between the side forms with either a conforming plate or by vibrating and oscillating finishing beams. The concrete shall be deposited without segregation in front of slip form paver across the whole width and to a height which at all times is in excess of the required surcharge. The deposited concrete shall be struck off to the necessary average and differential surcharge by means of the strike off plate or a screw auger device extending across the whole width of the slab. The equipment for striking-off the concrete shall be capable of being rapidly adjusted for changes of the average and differential surcharge necessitated by change in slab thickness or crossfall.

602.9.6.2 The level of the conforming plate and finishing beams shall be controlled automatically from the guide wires installed as per Clause 602.8 by sensors attached at

the four corners of the slip form paving machine. The alignment of the paver shall be controlled automatically from the guide wire by at least one set of sensors attached to the paver. The alignment and level of ancillary machines for finishing, texturing and curing of the concrete shall be automatically controlled relative to the guide wire or to the surface and edge of the slab.

602.9.6.3 Slip-form paving machines shall have vibrators of variable output, with a maximum energy output of not less than 2.5 KW per metre width of slab per 300 mm depth of slab for a laying speed upto 1.5 m per minute. The machines shall be of sufficient mass to provide adequate reaction during spreading and paving operations on the traction units to maintain forward movements during the placing of concrete in all situations.

602.9.6.4 If the edges of the slip formed slab slump to the extent that the surface of the top edge of the slab does not comply with the requirements of Clause 602.14, then special measures such as fixing of side forms held in position by screwed jacks or any other suitable device approved by the Engineer shall be taken to support the edges to the required levels and work shall be stopped until such time as the Contractor can demonstrate his ability to slip form the edges to the required levels.

Pavers with adequate width to pave the entire carriageway width in one go will be employed. Paving in part width will be avoided, except in unavoidable circumstances. In case of part width paving, care will be taken to ensure that while paving the next lane bond between the old concrete and newly laid concrete is properly formed to develop adequate bond strength between tie bars and concrete as specified in IRC:58 (Appendix-4 of IRC:58). Care shall be taken to avoid damage to the previous lane.

Work on next lane shall be permitted when the previously paved lane is cured for at least 14 days and is in a position to bear the weight of paving machines. When the wheels or crawler tracks are to ply on the already paved surface, necessary precautions shall be taken by placing protective pads of rubber or similar material so that texture is not damaged. The wheel or track shall be reasonably away from the edge to avoid damage to the previously paved slab.

Upon the instructions of the Engineer, Contractor shall scrape the concrete surface when in plastic state with a 3 m long tube float fixed with a long and stable handle before texturing. Tube float shall be of an alloy steel tube of 50 to 60 mm diameter with a long and stable handle. The length of tube float shall preferably be longer than half the length of slab i.e., half the distance between two transverse contraction joints. This operation shall be done to improve surface irregularity caused due to varied causes like frequent stoppages of work, surface deformation due to plastic flow etc. The tube float shall be placed at the centre of the slab parallel to longitudinal joint and pulled slowly and uniformly towards the edges. After the use of float tube, it shall be frequently cleaned before further use. The slurry removed shall be discarded. This activity shall be advanced laterally by providing an overlap of half the length of tube float. The removal of the cement slurry from the surface

shall be sufficient enough such that the texture is formed on a firm surface and is more durable. This operation, however, shall be carried out after removing bleeding water. This operation shall be done in the case of pavement construction using fixed form or slip form paving technique.

602.9.7 Semi-Mechanised and Labour-Oriented Construction Technique : Areas in which hand-guided methods of construction become indispensable shall be got approved by the Engineer in writing in advance. Such work may be permitted only in restricted areas in small lengths. Work shall be carried out by skilled personnel as per methods approved by the Engineer. The acceptance criteria regarding level, thickness, surface regularity, texture, finish, strength, of concrete and all other quality control measures shall be the same as in the case of machine laid work. Guidelines on the use of plants, equipment, tools, hauling of mix, compaction floating, straight edging, texturing, edging etc. shall be as per IRC:15 (Clause 9.10).

602.9.8 Transition slabs : At the interface of rigid and flexible pavement, at least 3 m long reinforced buried slab should be provided to give a long lasting joint at the interface. The details shall be as given in IRC:15 (Clause 9.10.11, Fig. 3).

602.9.9 Anchor beam and terminal slab beam adjoining bridge structures : Cement concrete slabs will expand during hot season and this will result in the building up of horizontal thrust on adjoining bridge structure. To contain this thrust RCC anchor beams are to be provided in the terminal slab. The terminal slab also needs to be provided with reinforcement to strengthen it. A typical arrangement of anchor beam and the terminal slab are shown in Fig. 2 IRC:15. In case of culverts, etc. where the concrete slabs are provided above the superstructure, there is no need to construct anchor beams and terminal slab. In case the concrete slab abuts with culvert structure, the construction of anchor beam and terminal slab will be necessary. The details of anchor beams/terminal slab beam shall be as given in IRC:15 (Clause 8.5.2, Fig. 2).

602.9.10 The treatment of PQC on Culverts : The PQC shall be taken over the culverts. At both ends of the abutment walls, expansion joint with 12 mm thick synthetic board shall be provided. When the span of the culvert is long and normal contraction joint is necessitated between these expansion joint the same shall be provided.

602.9.8 Surface texture

602.9.8.1 Tining : After final floating and finishing of the slab and before application of the liquid curing membrane, the surface of concrete slabs shall be textured either in the transverse direction (i.e., at right angles to the longitudinal axis of the road) or in longitudinal direction (i.e., parallel to the centreline of the roadway). The texturing shall be done by tining the finished concrete surface by using rectangular steel tines. A beam or a bridge mounted with steel tines shall be equipped and operated with automatic sensing and control devices from main paver or auxiliary unit. The tining unit shall have facility for adjustment of

the download pressure on the tines as necessary to produce the desired finish. The tining rakes shall be cleaned often to remove snots of slurry. The tines will be inspected daily and all the damaged and bent tines shall be replaced before commencing texturing. Tined grooves shall be 3 mm wide and 3 to 4 mm deep. Before commencing texturing, the bleeding water, if any, shall be removed and texturing shall be done on a firm surface. Normally, transverse tining will be preferred.

Transverse tining :

When the texturing is specified in transverse direction, a beam of at least 3 m length mounted with tines shall be moved in transverse direction to produce the texture. The grooves produced shall be at random spacing of grooves but uniform in width and depth. The spacing shall conform to a pattern shown below:

Random spacing in mm

10	14	16	11	10	13	15	16	11	10	21	13	10

The above pattern shall be repeated. Texturing shall be done at the right time such that the grooves after forming shall not close and they shall not get roughened. Swerving of groove patterns will not be permitted. The completed textured surface shall be uniform in appearance.

Longitudinal tinning :

Longitudinal tinning shall be done, if specified in the Contract. The texturing bridge shall be wide enough to cover the entire width of the carriageway but within 75 mm from the pavement edge. The centre to centre spacing between the tins shall be 18 to 21 mm. The width of tine texture shall be 3 mm and depth shall be 3 to 4 mm.

602.9.8.2 **Brush Texturing :** Alternatively on the instructions of the Engineer, the brushed texturing shall be applied. The brushed surface texture shall be applied evenly across the slab in one direction by the use of a wire brush not less than 450 mm wide but wider brushes normally of 3 m length are preferred. The brush shall be made of 32 gauge tape wires grouped together in tufts placed at 10 mm centres. The tufts shall contain an average of 14 wires and initially be 100 mm long. The brush shall have two rows of tufts. The rows shall be 20 mm apart and the tufts in one row shall be opposite the centre of the gap between tufts in the other row. The brush shall be replaced when the shortest tuft wears down to 90 mm long.

602.9.8.3 The texture depth shall be determined by the Sand Patch Test as described in the Clause 602.12. This test shall be performed at least once for each day's paving and

wherever the Engineer considers it necessary at times after construction as under:

Five individual measurements of the texture depth shall be taken at least 2 m apart anywhere along a diagonal line across a lane width between points 50 m apart along the pavement. No measurement shall be taken within 300 mm of the longitudinal edges of a concrete slab constructed in one pass.

602.9.8.4 Texture depths shall not be less than the minimum required when measurements are taken as given in Table 600-3 nor greater than a maximum average of 1.25 mm.

Table 600-3 Texture Depth

Time of Test	Number of Measurements	Required Texture Depth (mm)	
		Specified Value	Tolerance
1. Between 24 hours and 7 days after the construction, of the slab or until the slab is first used by vehicles.	An average of 5 measurements	1.00	±0.25
2. Not later than 6 weeks before the road is opened to traffic.	An average of 5 measurements	1.00	+0.25 -0.35

602.9.8.5 After the application of the brushed texture, the surface of the slab shall have a uniform appearance.

602.9.8.6 Where the texture depth requirements are found to be deficient, the Contractor shall make good the texture across the full lane width over length directed by the Engineer, by retexturing the hardened concrete surface in an approved manner.

602.9.9 Curing

602.9.9.1 Immediately after the surface texturing, the surface and sides of the slab shall be cured by the application of approved resin-based aluminized reflective curing compound which hardens into an impervious film or membrane with the help of mechanical sprayer.

Curing compounds shall contain sufficient flake aluminium in finely divided dispersion to produce a complete coverage of the sprayed surface with a metallic finish. The compound shall become stable and impervious to evaporation of water from the surface of the concrete within 60 minutes of application and shall be of approved type. The curing compounds shall have a water retention efficiency index of 90 percent in accordance with BS Specification No. 7542 or ASTM-C-309-81, type-2.

602.9.9.2 The curing compound shall not react chemically with the concrete and the film or membrane shall not crack, peel or disintegrate within three weeks of application. Immediately prior to use, the curing compound shall be thoroughly agitated in its containers. The rate of spread shall be in accordance with the manufacturer's instructions checked during the construction of the trial length and subsequently whenever required by the Engineer. The mechanical sprayer shall incorporate an efficient mechanical device for continuous agitation and mixing of the compound during spraying. To give continuous covering , the curing compound may be sprayed in two layers.

602.9.9.3 In addition to spraying of curing compound, the fresh concrete surface shall be protected for at least 3 hours by covering the finished concrete pavement with tents as described in Clause 602.7.2, during adverse weather conditions as directed by the Engineer. After three hours, the pavement shall be covered by moist hessian laid in two layers and the same shall then be kept damp for a minimum period of 14 days after which time the hessian may be removed. The hessian shall be kept continuously moist. All damaged/torn hessian shall be removed and replaced by new hessian on a regular basis.

602.9.9.4 The Contractor shall be liable at his cost to replace any concrete damaged as a result of incomplete curing or cracked on a line other than that of a joint as per procedure in IRC:SP:83.

602.10 Trial Length

602.10.1 The trial shall be constructed at least one month in advance of the proposed start of concrete paving work. At least one month prior to the construction of the trial length, the Contractor shall submit for the Engineer's approval a detailed method statement giving description of the proposed materials, plant, equipment and construction methods. All the major equipments like paving train, batching plant, tipping trucks etc., proposed in the construction are to be approved by the Engineer before their procurement. No trials of new materials, plant, equipment or construction methods, nor any development of them shall be permitted either during the construction of trial length or in any subsequent paving work, unless they form part of further approved trials. These trial lengths shall be constructed away from the carriageway but with at least a subbase layer below it.

602.10.2 The Contractor shall demonstrate the materials, plant, equipment and methods of construction that are proposed for concrete paving, by first constructing a trial length of slab, at least 100 m but not more than 300 m long for mechanised construction and at least 50 m long for hand guided methods. If the first trial is unsatisfactory, the Contractor shall have to demonstrate his capability to satisfactorily construct the pavement in subsequent trials.

602.10.3 The trial length shall be constructed in two parts over a period comprising at least part of two separate working days, with a minimum of 50 m constructed each day for mechanised construction and a minimum of 25 m on each day for hand guided construction.

The trial length shall be constructed at a paving rate (speed, around 1 m/hr similar) to that which is proposed for the main work.

602.10.4 Transverse joints and longitudinal joints of each type that are proposed for dowel-jointed unreinforced concrete slabs in the main work shall be constructed and assessed in the trial length. If in the trial length the construction of expansion joint and longitudinal joint is not demonstrated, the first 2 expansion joints and at least the first 150 m of longitudinal construction joint for mechanized paving in the main work, shall be considered as the trial length for these joints.

602.10.5 The trial length shall comply with the Specifications in all respects, with the following additions and exceptions:

602.10.5.1 Surface levels and regularity

a) In checking for compliance with Clause 902.3 the levels shall be taken at intervals at the locations specified in this Clause along any line or lines parallel to the longitudinal centre line of the trial length.

b) The maximum number of permitted irregularities of pavement surface shall comply with the requirements of Clause 902.4. shorter trial lengths shall be assessed pro-rata based on values for a 300 m length.

602.10.5.2 Joints

c) Alignment of dowel bars shall be inspected as described in Clause 602.10.7 in any two consecutive transverse joints. If the position or alignment of the dowel bars at one of these joints does not comply with Clause 602.6.5, if that joint remains the only one that does not comply after the next 3 consecutive joints of the same type have been inspected, then the method of placing dowels shall be deemed to be satisfactory. In order to check sufficient joints for dowel bar alignment without extending the trial length unduly, the Contractor may, by agreement with the Engineer, construct joints at shorter intervals than the normal spacing required in the Contract.

d) If there are deficiencies in the first expansion joint that is constructed as a trial, the next expansion joint shall be a trial joint. Should this also be deficient, further trial expansion joints shall be made as part of the trial length which shall not form part of the permanent works, unless agreed by the Engineer.

e) **Direction of Dowel bars/Tie bars :** The direction of dowel bars/tie bars at the curve portion shall be in such a way that these shall be radially in the direction of the radii and parallel to the top surface.

These shall also be perpendicular to the direction of transverse joint and longitudinal joint at the middle of the slab depth respectively. The direction of bonded portion of the dowel bars shall preferably be in approaching side of the traffic and unbonded portion shall be on the side where traffic is leaving the joint.

602.10.5.3 Density

In-situ density in trial length shall be assessed as described in Clause 903.5.2.2 from at least 3 cores drilled from each part of the trial length when the concrete is not less than 7 days old. Should any of the cores show honey-combing in the concrete, the trail length shall be rejected and the construction in the main carriageway shall not be permitted until further trials have shown that modification has been made which would result in adequate compaction.

602.10.5.4 Position of tie bars

Compliance with Clause 602.6.6 for the position and alignment of tie bars shall be checked by drilling additional cores from the slab unless they can be determined from cores taken for density.

602.10.5.5 Minimum of thirty (30) beams for flexural strength and thirty (30) cubes for compressive strength shall be prepared from the concrete delivered in front of the paving plant. Each pair of beams and cubes shall be from the same location/batch but different sets of beams and cubes shall be from different locations/batches. Compressive and flexural strength shall be tested after 28 days water curing in the laboratory.

At the age of 28 days, thirty (30) cores with diameter 150 mm shall be cut from the pavement slab when the thickness of PQC is more than 300 mm. In case the PQC thickness is less than 300 mm, the dia of core shall be 100 mm. The cores shall be suitably cut at both ends to provide a specimen of plain surface on both ends. The dia to height ratio of core shall be 1 to 2. (for cylindrical specimen of PQC of dia 150 mm, the variation in dia shall be $\pm$ 0.5 mm, a tolerance on height shall be $\pm$ 1 mm for a specimen of cylindrical height 300 mm or more). The test shall be conducted as per IS:516.

Concrete in the member represented by a core test shall be considered acceptable, if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength (characteristic strength) of the grade of the concrete specified for the corresponding age (28 days) and no individual core has a strength less than 75 percent.

602.10.6 Approval and acceptance

602.10.6.1 Approval of the materials, plant, equipment and construction methods shall be given when the trial length complies with the Specifications. The Contractor shall not proceed with normal working until the trial length has been approved. If the Engineer does not notify the Contractor of any deficiencies in any trial length within 10 days after the completion of that trial length, the Contractor may assume that the trial length, and the

materials, plant, equipment and construction methods adopted are acceptable after accepting the 28 days strength test cubes and cores intracted from trial length.

602.10.6.2 When approval has been given, the materials, plant, equipment and construction methods shall not thereafter be changed, except for normal adjustments and maintenance of plant, without the approval of the Engineer. Any changes in materials, plant, equipment, and construction methods shall entitle the Engineer to require the Contractor to lay a further trial length as described in this Clause to demonstrate that the changes will not adversely affect the permanent works.

602.10.6.3 Trial lengths which do not comply with the Specifications, with the exception of areas which are deficient only in surface texture and which can be remedied in accordance with Clause 602.9.8.6 shall be removed immediately upon notification of deficiencies by the Engineer and the Contractor shall construct a further trial length.

602.10.7.1 Inspection of dowel bars

602.10.7.1 Compliance with Clause 602.6.5. for the position and alignment of dowel bars at construction and expansion joints shall be checked by measurements relative to the side forms or guide wires.

602.10.7.2 When the slab has been constructed, the position and alignment of dowel bars and any filler board shall be measured after carefully exposing them in the plastic concrete across the whole width of the slab. When the joint is an expansion joint, the top of the filler board shall be exposed sufficiently in the plastic concrete to permit measurement of any lateral or vertical displacement of the board. During the course of normal working, these measurements shall be carried out in the pavement section at the end of day's work by extending slab length by 2 m. After sawing the transverse joint groove, the extended 2 m slab shall be removed carefully soon after concrete has set to expose dowels over half the length. These dowels can be tested for tolerances.

602.10.7.3 If the position and alignment of the bars in a single joint in the slab is unsatisfactory then the next two joints shall be inspected. If only one joint of the three is defective, the rate of checking shall be increased to one joint per day until the Engineer is satisfied that compliance is being achieved. In the event of non-compliance in two or more successive joints, the Contractor shall revert to the construction of fresh trial lengths and make any necessary alteration to concrete mix, paving plant or methods until the dowel bar position and alignment are satisfactory.

602.10.7.4 After the dowel bars have been examined, the remainder of the concrete shall be removed over a width of 500 mm on each side of the line of the joint and reinstated to the satisfaction of the Engineer. The dowels shall be inserted on both sides of the 1 m wide slab by drilling holes and grouting with epoxy mortar. Plastic sheath as per Clause 602.6.5.5 shall be provided on dowels on one of the joints. The joint groove shall be widened and sealed as per Clause 602.11.

602.11 Preparation and Sealing of Joint Grooves

602.11.1 General

All transverse joints in surface slabs shall be sealed using sealants described in Clause 602.2.8 and as for IRC:57.

602.11.2 Preparation of joint grooves for sealing

602.11.2.1 Joint grooves usually are constructed in first instance to provide the minimum width specified in the drawings when saw cut joints are adopted. They shall be widened subsequently by sawing before sealing. Depth/width gauges shall be used to control the dimension of the groove. Grooves are constructed in first instance just to provide a minimum width (3-5 mm) to facilitate development of cracks at such locations.

Subsequently before sealing, grooves are widened by sawing as per the dimensions in the drawing. Dimension of the grooves shall be controlled by depth/width gauge.

602.11.2.2 If rough arrises develop when grooves are made, they shall be ground to provide a chamfer approximately 5 mm wide. If the groove is at an angle upto 10^o from the perpendicular to the surface, the overhanging edge of the groove shall be sawn or ground perpendicular. If spalling occurs or the angle of the former is greater than 10 degree, the joint sealing groove shall be sawn wider and perpendicular to the surface to encompass the defects upto a maximum width, including any chamfer, of 20 mm for transverse joints and 10 mm for longitudinal joints. If the spalling cannot be so eliminated then the arrises shall be repaired by an approved thin bonded arrises repair using cementitious materials.

602.11.2.3 All grooves shall be cleaned of any dirt or loose material by air blasting with filtered, oil-free compressed air. The Engineer shall instruct cleaning by pressurized water jets. Depending upon the requirement of the sealant manufacturer, the sides of the grooves shall be sand blasted to increase the bondage between sealant and concrete.

602.11.2.4 The groove shall be cleaned and dried at the time of priming and sealing.

602.11.2.5 Before sealing the temporary seal provided for blocking, the ingress of dirt, soil etc., shall be removed. A highly compressible heat resistant paper-backed debonding strip as per drawing shall be inserted in the groove to serve the purpose of breaking the bond between sealant and the bottom of the groove and to plug the joint groove so that the sealant may not leak through the cracks. The width of debonding grip shall be more than the joint groove width so that it is held tightly in the groove. In the case of longitudinal joints, heat resistant tapes may be inserted to block the leakage through bottom of the joint. When hot poured sealant is used. When cold poured sealant is used a debonding tape of 1.0-2.0 mm thickness and 6 to 8 mm width shall be inserted to plug the groove so that the sealant does not enter in the initially cut groove.

602.11.3 Sealing with sealants

602.11.3.1 When sealants are applied, an appropriate primer shall also be used if recommended by the manufacturer and it shall be applied in accordance with his instructions. The sealant shall be applied within the minimum and maximum drying times of the primer recommended by the manufacturer. Priming and sealing with applied sealants shall not be carried out when the naturally occurring temperature in the joint groove to be sealed, is below 7°C.

602.11.3.2 If hot applied sealant is used (MAF more than 10 percent) it shall be heated and applied from a thermostatically controlled, indirectly heated preferably with oil jacketed melter and pourer having recirculating pump and extruder. For large road projects, sealant shall be applied with extruder having flexible hose and nozzle. The sealant shall not be heated to a temperature higher than the safe heating temperature and not for a period longer than the safe heating period, as specified by the manufacturer. The dispenser shall be cleaned out at the end of each day in accordance with the manufacturer's recommendations and reheated material shall not be used.

602.11.3.3 Cold applied sealants with chemical formulation like polysulphide/ polyurethene/silicon as per IRC:57 shall be used when requirement of MAF is 25 percent or more. These shall be mixed and applied within the time limit specified by the manufacturer. If primers are recommended they shall be applied neatly with an appropriate brush.

602.11.3.4 The sealants applied at contraction phase of the slabs would result in bulging of the sealant over and above the slab. Therefore, the Contractor in consultation with the Engineer, shall establish the right temperature and time for applying the sealant. Thermometer shall be hung on a pole at the site for facilitating control during the sealing operation.

602.11.3.5 Sealant shall be applied, slightly to a lower level than the slab with a tolerance of 3 ± 1 mm.

602.11.3.6 During sealing operation, it shall be seen that no air bubbles are introduced in the sealant either by vapours or by the sealing process. The sealant after pouring, shall be allowed to cured for 7 days or for a period as per instructions of manufacturers.

602.12 Measurement of Texture Depth – Sand Patch Method

602.12.1 The following apparatus shall be used:

i) A cylindrical container of 25 ml internal capacity;

ii) A flat wooden disc 64 mm diameter with a hard rubber disc, 1.5 mm thick, next to one face, the reverse face being provided with a handle;

iii) Dry natural sand with a rounded particle shape passing a 300 micron IS sieve and retained on a 150 micron IS sieve.

602.12.2 **Method :** The surface to be measured shall be dried, any extraneous mortar and loose material removed and the surface swept clean using a wire brush both at right angles and parallel to the carriageway. The cylindrical container shall be filled with the sand, tapping the base 3 times on the surface to ensure compaction, and striking off the sand level with the top of the cylinder. The sand shall be poured into a heap on the surface to be treated. The sand shall be spread over the surface, working the disc with its face kept flat in a circular motion so that the sand is spread into a circular patch with the surface depressions filled with sand to the level of peaks.

602.12.3 The diameter of the patch shall be measured to the nearest 5 mm. The texture depth of concrete surface shall be calculated from 31000/(DxD) mm where D is the diameter of the patch in mm.

The dimensions of Tining i.e. width, depth and landwidth shall be controlled by depth/width guage.

6.2.12.4 **Measurrement of Texture Depth** - Tining

6.2.12.4.1 The following apparatus shall be used :

i) Tire Tread Depth Guage

A stainless steel tire trea depth gauge with graduations with least count of 1.0 mm. The gauge end may be modified to measure depth of tine texture.

ii) A stainless steel calipper to measure spacing of tines. If necessary the calipper may be modified to measure the spacing and width of tine texture. The guage shall be used after making necessary calibration.

iii) Wire brush

iv) Coborundum stone

v) Steel straight edge to remove snots etc. sticking to be surface. The straight edge may be of 6 x 25 x 300 mm size.

602.12.4.2 **Test Section**

A unit of testing shall be 75 m per lane. If the length of constructiobn is less than 75m it shall be taken as one unit.

602.12.4.3 **Test Procedure**

In each 75 m section, along the diagonal line, 10 points shall be selected for making checks

of depth, width and spacing of tine grooves. The surface where tests are to be conducted shall be cleared carefully with a wire brush or a steel straight edge or using a corborundum to remove any upward projection of concrete. When the base plate of the gauge is in contact with the concrete surface, the gauge shall be pressed to the bottom of groove shall also be measured and recorded at this location. At the same location, the spacing of tines shall be measured to verify whether the pattern recommended in Clause 602.9.9.2 is complied or not.

602.12.4.4 Calculation

The average of depth and width at 10 locations shall be calculated and recorded to the nearest 1mm. The spacing of spectrum measured at 10 locations shall be recorded separately.

602.12.5 The average depth shall be within 3 to 4 mm. When the depth is less than 2.5mm and in excess of 4.5 mm, the Contractor shall stop concreting till he corrects his tine brush or replaces it. The sensors associated with work shall be again calibrated to achieve the required texture. The textured groove less than 2.5 mm shall be re-grooved using concrete saw at the cost of Contractor variation in texture width in the range of 3+1 mm and 3 - 0.5 mm will be acceptable. Variation of width in excess of this range, the cotractor shall stop his work to correct his brush and technique. When the spacing of spectrum is not satisfactory, the contractor shall replace the entire brush.

602.13 Opening to Traffic

No vehicular traffic shall be allowed to ply on the finished surface of a concrete pavement within a period of 28 days of its construction and until the joints are permanently sealed. The road may be opened to regular traffic after completion of the curing period of 28 days and after sealing of joints is completed including the construction of shoulder, with the written permission of the Engineer.

602.14 Acceptance Criteria in Quality and Distress

i) **Tolerances for Surface Regularity, Level, Thickness and Strength :**

The tolerances for surface regularity, level, thickness and strength shall conform to the requirements given in Clause 903.5. Control of quality of materials and works shall be exercised by the Engineer in accordance with Section 900.

ii) **Tolerances in Distress :**

The acceptance criteria with regard to the types of distresses in rigid pavement shall be as per IRC:SP-83. "Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements". The cracks (of severity rating not more than 2) which

may appear during construction or before completion of Defect Liability Period shall be acceptable with suggested treatments as given in Table :600-4 .

In case of PQC slabs having cracks of severity rating more than 2 i.e. cracks of width more than 0.5 mm for single discrete cracks, multiple and transverse cracks and cracks of width more than 3 mm in case of longitudinal cracks and of depth more than half of the PQC slabs, shall be removed and replaced.

602.15 Measurements for Payment

602.15.1 Cement Concrete pavement shall be measured as a finished work in square metres with specified thickness. The volume to be paid for will be calculated on the basis of thickness and plans shown on the drawings and adjusted for the deficiency in thickness. No additional payment shall be made for extra thickness of the slab. The full payment will be made for this item after 28 days strength of the concrete is found to be satisfactory. Interim payment may be made after 14 days of curing.

The unit for measurement for concrete pavement shall be the cubic metre of concrete placed, based on the net plan areas for the specified thickness shown on the drawings or directed by the Engineer. The rate shall include all provisions of these Specifications and shall include the provision of all materials, their storage, polythene film, concrete,mixing, transport, placing, compacting, finishing, curing together with all formwork, and including testing and submission of test certificates and records . The unit rate as entered in the Bill of Quantities shall also include all costs of contraction, expansion, construction, and longitudinal joints. It shall also include provision of joint filler, caulking rod, debonding strip, sealant primer, joint sealant, dowel bar and tie rod.

602.15.2 Pavement thickness

All precautions and care shall be taken to construct pavements having uniform thickness as shown on the plans.

A day's work is considered as a 'lot' for calculating the average thickness of the slab. Average thickness of the slab shall be within tolerence limits prescribed in Table 900-1. No extra payment shall be made for the thickness more than the thickness prescribed in the drawing.

602.16 Rate

The Contract unit rate for the construction of the cement concrete shall be payment in full for carrying out the operations required for the different items of the work as per these Specifications including full compensation for all labour, tools, plant, equipments, testing and incidentals to complete the work as per Specifications, providing all materials i.e. aggregates, dowel bars, tie bars, PVC membrane, cement, stabilizers (lime, cements or

TABLE 600-4 REPAIR ACTIONS FOR SEVERITY RATING* UPTO 2 IN CONCRETE PAVEMENTS

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action for the case d<D/2
1	**2**	**3**	**4**	**5**	**6**
	CRACKING				
1	Single Discrete Crack Not intersecting with any joint	w = width of crack	0	Nil, not discernible	No Action
		L = length of crack	1	w<0.2 mm, hair cracks	
		d = depth of crack D = depth of slab	2	w=0.2-0.5 mm, discernible from slow-moving car	Seal without delay
2	Single Transverse (or Diagonal) Crack intersecting with one or more joints	w = width of crack	0	Nil, not discernible	No Action
		L = length of crack	1	w < 0.2 mm, hair cracks	Route and Seal with epoxy
		d = depth of crack D = depth of slab	2	w = 0.2 - 0.5 mm, discernible from slow vehicle	
3	Single Longitudinal Crack intersecting with one or more joints	w = width of crack	0	Nil, not discernible	No Action
		L = length of crack	1	w < 0.5 mm, discernable from slow moving vehicle	Seal with epoxy, if L>1 m
		d = depth of crac D = depth of slab	2	w = 0.5 - 3.0 mm, discernible from fast vehicle	Route seal and stitch if L>1m
4	Multiple Cracks intersecting with one or more joints or cracks	w = width of crack	0	Nil, not discernible	No Action
		L = length of crack	1	w < 0.2 mm, hair cracks	Seal, and stitch if L>1 m
		d = depth of crack D = depth of slab	2	w = 0.2 - 0.5 mm, discernible from slow vehicle	

S.No.	Type of Distress	Measured Parameter	Degree of Severity	Assessment Rating	Repair Action for the case d<D/2
	SURFACE DEFECTS				
5.	Ravelling or Honeycomb type surface	r = area damaged surface/total surface of slab (%) h = maximum depth of damage	0	Nil, not discernible	No action
			1	r < 2%	Local repair of areas damaged
			2	r = 2 – 10%	and liable to be damaged.
6.	Scaling	r = damaged surface/total surface of slab (%) h = maximum depth of damage	0	Nil, not discernible	No action.
			1	r < 2%	Local repair of areas damaged and liable to be damaged.
			2	r = 2 - 10%	

***** 5 level rating system : 0-Not Discernale, 1 – Minor, 2 – Moderate, 3 – Major, 4 – Extreme and 5 – Unsafe / Unserviceable

any other stabilizers accredited by IRC) etc. to be incorporated in the work including all royalties, fees, storage, rents where necessary and all leads and lifts. No separate payment will be made for construction of trial length and the tests carried out on the same.

602.17 Strengthening of Existing Pavement with Rigid Pavement

IRCSP:17 and IRC:SP: 76 may be referred for the design and construction of rigid pavement over rigid and flexible pavements including White Topping (WT), Thin White Topping (TWT) and Ultra Thin White Topping (UTWT) for different types of traffic (low to heavy), details of which are given in Section 604.

602.18 Maintenance : IRC:SP:83 covers the detailed methodology for repair and maintenance of Rigid pavements including full depth and partial depth repair methodology.

603 ROLLED CEMENT CONCRETE BASE

Deleted.

604 WHITETOPPING

604.1 Scope

604.1.1 Whitetopping is a Portland Cement Concrete (PCC) overlay constructed on the top of an existing bituminous pavement. It is, thus, a rehabilitation or structural

strengthening alternative of a bituminous pavement. This emerging concept has found real extended application for rehabilitating the old bituminous pavements. This provides an effective remedy where rutting or other failure of bituminous pavement is a recurring problem. This composite type pavement provides a cost effective rehabilitation for aging bituminous pavements of the country.

604.1.2 Whitetopping upto a thickness of 100 mm is known as Ultra Thin Whitetopping. For a thickness from 100 mm upto 200 mm is called Thin Whitetopping and for a thickness of more than 200 mm is called Conventional Whitetopping. Ultra Thin Whitetopping relies upon the bonding between underlined bituminous layer and overlaid Portland Cemente Concrete (PCC) layer by milling the existing bituminous layer. These are normally suitable for parking lot or very low volume roads. Thin Whitetopping may be suitable for medium volume roads and Conventional Whitetopping is for moderate to heavy trafficked roads. For details of different types of Whitetopping IRC:SP:76 can be referred.

604.2 Materials

604.2.1 Cement

Any of the following types of cement capable of achieving the design strength may be used with prior approval of the Engineer:

i) Ordinary Portland Cement, 43 Grade, IS:8112

ii) Ordinary Portland Cement, 53 Grade, IS:12269

iii) Portland Pozzolana Cement, IS:1489

iv) Portland Slag Cement, IS:455

Preference should, however, be to use 43/53 Grade cement, as the grade of required concrete is more than M 40.

While using 53 Grade Cement, fly ash upto 20 percent by weight of cementitious material may be added. The mix shall be designed as per IRC:44 or IS:10262. If ground granulated blast furnace slag as per IS:10289 is used, it shall be upto 50 percent by weight of Ordinary Portland Cement. Slag shall be added only in Ordinary Portland Cement (53 Grade).

Site mixing of fly ash and ground granulated blast furnace slag shall be permitted only after ensuring availability of the equipments at site for uniform blending through a specific mechanized facility with automated process control like batch mix plants conforming to IS:4925 and IS:4926. Site mixing will not be allowed otherwise.

If the soil around has soluble salts like sulphates in excess of 0.5 percent, the cement used shall be sulphate resistant and shall conform to IS:12330.

Guidance may be taken from IRC: 44 for ascertaining the compressive/flexural strength of cement concrete required to match with the prescribed design strength of concrete. Cement to be used may preferably be obtained in bulk form. If cement in paper bags is proposed to be used, there shall be bag-splitters with the facility to separate pieces of paper bags and dispose them off suitably. No paper pieces shall enter the concrete mix. Bulk cement shall be stored in accordance with Clause 1014. The cement shall be subjected to acceptance test just prior to its use.

604.2.2 Chemical Admixture

Admixtures conforming to IS:9103 and IS:6925 may (upto 2 percent by weight of cement as per IS:456) be used to improve workability of the concrete or extension of setting time, on satisfactory evidence that they will not have any adverse effect on the properties of concrete with respect to strength, volume change and durability.

604.2.3 Aggregates

604.2.3.1 Aggregates for pavement concrete shall be natural material complying with IS:383 with a Los Angeles (LA) Abrasion not more than 35 percent. The limits of deleterious materials shall not exceed the requirements set out in Table 600-2. Furhter these will meet the requirements laid down in Clause 602.2.4.5.1

604.2.4 Coarse aggregate : Coarse aggregates shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone or crushed gravel and shall be devoid of pieces of disintegrated stone, soft, flaky, elongated, very angular or splintery pieces. Aggregates should normally be rough textured and cubical in shape. Use of modern crushing technology for producing aggregates is considered desirable. The maximum size of coarse aggregates shall not exceed 31.5 mm in case of TWT/Conventional Whitetopping and 25 mm in case of UTWT. The flakiness and elongation index of aggregates shall be less than 35 percent. No aggregates which has water absorption more than 2 percent shall be used in the concrete mix. The aggregates shall be tested for soundness in accordance with IS:2386 (Part V). After 5 cycles of testing, the loss shall not be more than 12 percent if sodium sulphate solution is used or 18 percent if magnesium sulphate solution is used. If aggregates are doubtful for alkali aggregate reactivity, IS:456 may be referred for guidance. If aggregates are not free from dirt, the same may be washed and drained for at least 72 hours before batching. In such a situation the absorbed moisture content shall be carefully taken into account while calculating water content in the mix.

604.2.5 Fine aggregate : The fine aggregates shall consist of clean natural sand or crushed stone sand or a combination of the two and shall conform to IS:383. Fine aggregates shall be free from soft particles, clay, shale, loam, cemented particles, mica and organic and other foreign matter. The fine aggregates shall not contain deleterious substances within the limites given in Table 600-2.

The mix produced in the laboratory and the field should be satisfactory in all respects and should comply with the requirement of these Specifications.

604.2.6 Water : Water used for mixing and curing of concrete shall be clean and free from injurious amount of oil, salt, acid, vegetable matter or other substances harmful to the finished concrete. It shall meet the requirements stipulated in IS:456. Potable water is generally considered satisfactory for mixing and curing.

604.2.7 Mineral admixtures : In case of Conventional Whitetopping, Ultra Thin Whitetopping and Thin Whitetopping following materials may be added as mineral admixtures as per their availability:

i) Fly ash grade I (as per IS 3812-2003)

ii) Ground Granulated blast furnace slag (as per IS:12089)

iii) Silica fume (as per IS:15388-2003, IS:456-2000 and IRC:SP:70)

The silica-fume as per design is used where high performance concrete is the requirement of the design. It shall be added in suitable dozes normally @ 3-10 percent by weight of cementitious material.

To improve the ductility and fatigue resistance of high performance/high strength concrete, polymeric fiber may be added in the concrete 0.2-0.4 percent by weight of cement and/or steel fiber as per IRC:SP:46. Polymeric fiber shall have water absorption less than 0.3 percent and shall not affect the properties of concrete (i.e. reduction in the strength not more than 5 percent). Entrapped air content in the concrete shall not be more than 3 percent except where freezing and thawing is taking place.

604.2.8 Fibers

Fibers may be used subject to the provisions in the design/approval by the Engineer to reduce the shrinkage cracking and post-cracking. The fibers may be steel fiber as per IRC:SP:46 or polymeric Synthetic Fibers shall meet the specification laid down in Claused 602.2.3.1.

604.2.9 Storage of materials

All materials shall be stored in accordance with the provisions of Clause 1014 of the Specifications and other relevant IS Specifications as laid down in Clause 602.2.9.

604.2.10 Mix proportioning and strength of concrete

Following designed concrete mixes may be used for construction of all types of whitetopping (Conventional/TWT/UTWT):

i) Conventional cement concrete

ii) Fiber Reinforced concrete using fibers viz. polypropylene, polyethylene, nylon, polyester, steel (IRC:SP:46) etc.

iii) High Performance concrete using silica fume upto 3-10 percent by weight of cementitious material with and without using fly ash (upto 20 percent) or slag up to 50 percent by weight of cement, (IRC:SP:70)

iv) High Performance fiber reinforced concrete using specified fibers and mineral admixtures as per IS:456 using a doze of chemical admixture @ upto 2.0 percent by weight of cement.

Concrete mixes used are so proportioned that the concrete mix generally produces concrete of minimum characteristic compressive strength M 40 or more than M 40 at 28 days. High

performance concrete of compressive strength M 50 is normally preferred. The high strength high performance concrete is essential for fast track construction which is achieved by using early setting cements with microsilica as an essential additive.

UTWT/TWT projects are generally constructed with concrete of mix, having lower water/ cement ratio, less than 0.40. It is, however, preferable to have a water/cement ratio around 0.28 to 0.30. The workability/slump requirement (25-50 mm) may be conveniently achieved by the use of plasticizer. Rich mixes may have higher cement content (but not greater than 540 kg/m^3). Extra precautions are required while using very high cement content with regard to the heat of hydration. High cement content will lead to extra heat of hydration and cracking. The minimum cement content is 360 kg/m^3. The higher strength is derived not by increasing the cement content but by reduced water content. A typical mix proportion for academic interest is given in Table 604.6 which may be used as a guidance to achieve characteristic compressive strength of M 50. Table 600.6 is only for the guidelines and help in the mix design. The same mix proportions may be adopted in case of Conventional Whitetopping with precautions of curing, ambient temperature, slump and temperature of concrete.

When designing concrete pavements, the flexural strength (modulus of rupture) of concrete is used rather than its compressive strength, as concrete fails in flexure rather than in compression. The mixes shall be designed as per IRC:44 or IS:10262. The minimum flexural strength or modulus of rupture (Third point loading) of the concrete shall be 45 kg/cm^2 for responding to the minimum grade of concrete i.e. M 40 at 28 days. However, it is preferred to have a flexural strength of 50-60 kg/cm^2 (third Point Loading) as per IS:516.

604.3 Trial Length

604.3.1 The trial length shall be constructed at least one month in advance of the proposed work. Before doing actual construction of Conventional Whitetopping, Thin Whitetopping, Ultra Thin Whitetopping, a trial length of 50 m is essential as per the guidelines similar to Conventional rigid pavement (602.10).

604.4 Construction

604.4.1 The steps of constructions for Conventional Whitetopping, Thin Whitetopping and Ultra Thin Whitetopping are given as under:

i) **Milling :** The milling of the existing asphalt pavement provides removal of rutting. The depth of milling (25–50 mm) depends upon the types and severity of distress.

Table 600.6 Typical Mix Proportions

Sl. No.	Ingredients	Weight in kg
1.	Ordinary Portland Cement 43 or 53 Grade	440
2.	Coarse Aggregate	947
3.	Fine Aggregate (Natural)	596
4.	Polymeric Fibers	0.9
5.	Water/Cement Ratio	0.28 (desirable, but not more than 0.40)
6.	Water	170 liter or kg
7.	Fly ash	88
8.	Silica fume	59
9.	Chemical Admixture	0.5% by weight of cement (desirable but not more than 2%)

Note 1) Crushed sand may also be used conforming to IS:383-1970.

2) As per IS:383 permissible limit of 150 micron IS sieve is increased to 20%.

3) Crushed sand blended with river sand can also be used.

ii) **Repair to Existing Pavement :** The milled pavement shall be repaired in respect of cracks etc. The surface of the asphalt shall be flushed with water to aid in cleaning, before overlay is applied. Needed profile correction course may be applied as per IRC:SP:76.

iii) **Cleaning :** After milling or providing the profile correction course, atop the existing asphalt pavement, the top surface is cleaned to ensure bonding between the existing asphalt pavement and the new concrete overlay.

iv) After the milling operation/laying profile correction course, form work using steel channels or girder are fixed and stability of these is ensured simultaneously. Concrete is placed, finished textured and cured using conventional paving techniques and materials. After the laying of PCC, runner beam shall simultaneously be provided without causing vibration/disturbance to the newly laid UTWT/TWT. Use of semi mechanized method, slip form paver or fixed form paver may be adopted as per IRC:15 based on size of project and availability of the space and equipment.

Curing compound/water should be applied twice the normal rate. The timing of the texturing operation is important.

v) For low speed, municipal or urban projects, a burlap drag, turf drag, or coarse broom texture is sufficient. For high-speed interstate and other primary routes, tining provides excellent long-term skid resistance.

604.4.2 **Drainage :** Drains, inlets and manholes must be raised to match the elevation of the new pavement.

604.4.3 **Joints**

The locations and type of joints shall be as shown in the drawing. Joints shall be constructed depending upon their functional requirement as detailed in the IRC:SP 76. The location of the joints should be transferred accurately at the site and mechanical saw cutting of joints done as per stipulated dimensions. It should be ensured that the full required depth of cut is made from edge to edge of the pavement. Sawing of joints shall be carried out with diamond studded blades soon after the concrete has hardened to take the load of the sawing machine and personnel without damaging the texture of the pavement.

Sawing operation could start as early as 5-6 hours after laying of Whitetopping but not later than 18 to 20 hours depending upon the ambient temperature, wind velocity and relative humidity and required maturity of concrete achieved for this purpose.

If the kerb is cast integrally with the main pavement slab, the joint cutting shall also be extended to the kerb.

Sawing should not be initiated when the compressive strength of the concrete is less than 2 MPa and should be completed before it attains the compressive strength of 7 MPa.

The ratio of the length (longest dimension) to width (shortest dimension) of any given panel is recommended to be not more than 1.20. Conventional types of joints are being adopted in the construction of conventional whitetopping. In the case of UTWT/TWT, construction of these joints is slightly modified as:

i) Contraction Joints

ii) Expansion Joint

iii) Construction Joint

iv) Longitudinal Joints

Initially, 3-5 mm joint may be cut within 5-20 to a depth of 1/3 of the slab’s depth.

Short joint spacing is critical for the good performance of UTWT/TWT projects. Details of the joints and their sealing with sealant or preformed seals as shown in IRC:SP:76. No expansion joint is required, in case of UTWT/TWT, however, at every 15 m length, a wooden board of 10 mm may thickness be used as construction butt joint with 3 tie bars in each panel with maximum joint spacing of 1.0 m. When width of UTWT/TWT lane is more than 1.25 m, a longitudinal joint is required.

604.4.4 Surface Levels, Regularity and Surface Unevenness : The levels of sub-base/base and wearing course shall be within $\pm$ 6 mm. The number of irregularity shall be as per Table 900-2(b) and 900-2(c).

604.5 Opening to Traffic

The traffic can be opened when the UTWT/TWT has attained the desired strength depending on the traffic loading condition. Usually, traffic may be opened after 28 days (or at the age at which characteristic strength minimum 280 kg/cm^2 is achieved) of casting Paving Quality Concrete (PQC)/PCC slabs.

604.6 Acceptance Criteria : Concrete Beams of size, 100 mm x 100 mm x 500 mm and concrete cubes (100 mm) as per IS:516 shall be cast for each 150 cum of concrete or on each days work.

Average compressive and flexural strength of specimen = characteristic strength $\pm$1.65 x s

Where s is the standard deviation

In case of doubt 50 mm dia cores for Ultra Thin Whitetopping and 100 mm dia cores for Thin Whitetopping and Conventional Whitetopping may be cut and strength of these cores shall be conforming to Clause 602.3.3.

604.7 Measurement for Pavement

Conventional Whitetopping, Thin Whitetopping and Ultra Thin Whitetopping shall be measured as a finished work in square metres with specified thickness. The volume to be paid for will be calculated on the basis of thickness and plans shown on the project drawings. No additional payment shall be made for extra thickness of the slab. Thickness less than the prescribed shall be acceptable as under:

UTWT,	5 mm is not more than in two continuous panels
TWT,	8 mm in not more than two panels
Conventinal	10 mm is not more than in two continuous panels

The full payment will be made to this item after 28 days strength of the concrete is found to be satisfactory. Interim payment may be made after 14 days curing the measurement shall be made as per Clause 602.15.1.

604.8 Pavement Thickness

All precautions and care shall be taken to construct pavements having uniform thickness as called for on the plans.

Thickness of the whitetopping shall be calculated on the basis of level data of the cement concrete pavement and the underlying sub-base taken on a grid of 5 m x 3.5 m. While calculating average thickness, the thickness greater than 6 mm shall be considered as 6 mm.

A day's work is considered as a 'lot' for calculating the average thickness of the slab. Average thickness of the slab shall be within the tolerance limits prescribed in Table 900-I. No extra payment shall be made for thickness more than 6 mm.

604.9 Rate

The Contract unit rate for the construction of the cement concrete shall be payment in full for carrying out the operations required for the different items of the work as per these Specifications including full compensation for all labour, tools, plant, equipments, testing and incidentals to complete the work as per Specifications, providing all materials i.e aggregates, dowel bars, tie bars, PVC sheet, cement, stabilizers (lime, cements or any other stabilizers accredited by IRC) etc to be incorporated in the work including all royalties, fees, storage, rents where necessary and all leads and lifts. No separate payment will be made for construction of trial length and tests carried out on the same.

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700

Geosynsthetics

701 GEOSYNTHETICS IN ROAD AND BRIDGE WORKS

701.1 Scope

This specification covers the various applications of Geosynthetic materials in road and bridge works including supplying and laying as per special provisions.

“Geosynthetic is a general classification for all synthetic materials used in geotechnical engineering application. It includes geotextiles, geogrids, geonets, geomembranes and geocomposites etc.

i) **Geotextiles** : They are indeed textiles in traditional sense, but consists of synthetic fibers. These fibers are generally non biogradable. The synthrtic fibers are made into a flexible, porous fabric by standard weaving machinery or are matted together in a random, or nonwoven, manner. Some are also knit. Woven geotextiles are produced by weaving or interlacing two or more sets of fibers usually at right angles. Non-woven geotextiles are produced by mechanical bonding or needle punching of randomly oriented fibers. In some cases, non-woven fibers may be bonded thermally or chemically. Geotextiles generally available have thickness varying from 0.25 mm to 7.5 mm and have a mass per unit area 150 to 2000 g/m^2 referred as gsm. The major point is that they are porous to water flow across their manufactured plane or also within their plane, but to a widely varying degree. They are used in various geotechnical engineering applications. There are several specific application areas for Geotextiles that have been developed; however, the fabric always perform at least five discrete functions i.e., separation, reinforcement, filtration, drainage and moisture barrier (when impregnated).

ii) **Geogrids** : These are primarily made of synthetic materials. Rather than being a woven, nonwoven, or knit textile; geogrids are formed into a very open, grid like configuration, i.e., they have large apertures. The geogrids are relatively high strength, high modulus, low-creep-sensitive polymers with apertures varying from 10 to 100 mm in size. The openings/holes in geogrids are either elongated ellipse, near squares with rounded corners, squares or rectangles. Geogrids may be used for the purpose of separation but invariabl they are being used in some form of reinforcement.

iii) **Geonets** : Geonets constitute another specialized segment of geosynthetics. They are usually formed by a continuous of polymeric ribs at acute angle to one another. When the ribs are opened, relatively

large apertures are formed in a netlike configuration. Geonets are like geogrids in configuration but they are used for the purpose of drainage. It is to be noted that geonets are always used with a geotextile, geomembrane or other material on their upper or lower surfaces. Clearly geonets are used for their drainage capability while geogrids are used for reinforcement.

iv) **Geocomposite :** A geocomposite consists of a combination of geotextile and geogrid; or geogrid and geomembrane; or geotextile, geogrid and geomembrane or any of these three materials with another material in laminated or composite form. Prefabricated Vertical Drains or Band Drains, which are widely used for accelerating the consolidation of soft soils also come under the category of geocomposites.

v) **Geomembranes :** Geomembranes are also synthetic materials but they are impervious and made of thin sheets of rubber or plastic materials used primarily for lining and cover of liquid-or solid-storage facilities.

701.2 Material Testing and Acceptance

Unless otherwise stated, the Geosynthetic materials shall conform to the requirements as under:

702.2.1 Geotextile : Geotextile shall be made of polyethylene or polypropylene or polyester or similar fibers, either woven or nonwoven or **knitted** in variety, through machine made process of heat bonding or needle punching or weaving techniques. These fabrics are required to pass water through but retain the soil particles, which require specific cross-plane permeability or permittivity and apparent opening size or equivalent opening size or 0_{95}. The above two requirements along with the requirement of strength and durability denote general characteristics of geotextiles to be used.

The type of geotextile to be used in a particular application shall be decided on the basis of design. Since the Geotextiles become integral part of any structure, whenever they are being used, it is necessary that the geotextile chosen should have sufficient strength to withstand the construction and other stresses, which a fabric is likely to bear during its life span. Table 700-1 specifies the minimum strength properties requirement for application in road works. The hydraulic properties requirement are given in the subsequent paragraphs. The properties specified are minimum average roll value in the weakest direction. The relevant test standards to determine the specified properties have also been indicated in the same table. The values given in the Table 700-1 are default values, which provide for sufficient survivability under most construction conditions. The Engineer based on engineering design, may specify properties other than those listed in the Table 700-1.

Table 700-1 Geotextile strength property requirements

Sl No	Geotextile installation condition	Type of geotextile recommended	Strength property requirement * (MARV)							
			Grab strength in N as per ASTM D 4632		Tear strength in N as per ASTM D 4533		Puncture strength in N as per ASTM D 4833		Burst strength in N as per ASTM D3786	
			Elongation at failure							
			<50 %	>50 %	<50 %	>50 %	<50 %	>50 %	<50 %	>50 %
1	Harsh installation condition	Type I	1400	900	500	350	500	350	3500	1700
2	Moderate installation condition	Type II	1100	700	400	250	400	250	2700	1300
3	Less severe installation condition	Type III	800	500	300	180	300	180	2100	950

* All numeric values in the above table represent Minimum Average Roll Value (MARV) in weaker principal direction. The MARV is derived statistically as the average value minus two standard deviations. A specification based on MARV means that 97.72 percent of the product is required to meet or exceed the specified values.

Note: 1. Type I class of geotextile is specified for more severe or harsh installation conditions, where there is a greater potential for geotextile damage and Type II and III are specified for less severe conditions.

2. When the Geotextiles are joined together by field sewing, the seam strength should be 90 percent of the material's tensile strength. All factory or field seams should be sewn with thread as strong as the material in the fabric. The values applied to both field and manufactured seams.

3. Contracting agency may require a letter from the supplier certifying that the geotextile meets specifications requirements.

Ultraviolet Stability

Typical reductions can be seen in the physical properties of all geotextiles after exposure to sunlight for a certain period of time. The amount of the time required to undergo a

specific degree of loss varies with the product, the exposure environment and the time of exposure. Table 700-2 gives specifications for ultraviolet light degradation.

Table 700-2 Geotextile Requirements for Ultra Violet Light Degradation

S.No	Properties of Fabric	Test Methods	Units	Requirements (Retained Strength)
1.	Grab Strength	ASTMD 4632	N	Not less than 50% after 500 hrs of exposure
2.	Tear Strength	ASTMD 4533	N	
3.	Puncture Strength	ASTMD 4833	N	
4.	Burst Strength	ASTMD 3786	kPa	

701.2.2 Geogrid : Geogrid shall be made from integrally jointed, mono or bi-directionally oriented or stretched meshes made from polyethylene or polypropylene or polyester or similar polymer, with high secant modules, in square, rectangular, hexagonal or oval mesh form. Their junction strength shall be high with high creep resistance, and dimensional stability. Their open structure shall permit effective interlocking with soil, aggregates, rock etc. They shall be used as a tensile member or reinforcement. The following abbreviations and definitions are generally used with geogrids.

CMD- Cross Machine Direction

MD- Machine Direction

UNIAXIAL GRID- A geogrid which has been manufactured with high junction strength and high tensile strength and modulus in one direction only.

BIAXIAL GRID- A geogrid which has been manufactured with high tensile strength in two directions perpendicular to one another.

DIRECTION OF REINFORCEMENT- Refers to the orientation that the geogrid is used for a particular project, which is along the machine direction (roll direction) for uniaxial geogrid.

701.2.3 Geonet : Geonet shall be made from a single extruded unoriented process from polyethylene or polypropylene or similar polymer. It shall have square or rectangular net shape aperture when used for protective works like gabions and mattresses. While in polygonal aperture it shall be used as a separator. It shall not be used as soil reinforcement

due to its high creep characteristics, neither as a slope reinforcement or soil retaining wall or asphaltic reinforcement. Geonets used in protective works for highway structures shall be atleast 650 gm/sq.m in unit weight. It shall be black in colour, available in roll form in suitable width.

701.2.4 **Geomembrane** : Geomembrane shall be made from PVC or polyethelene sheets of atleast 0.8 mm thickness, duly protected from ultraviolet exposure with 2.5 per cent carbon black, in black colour, supplied in roll form with 3 m or above width. The joints of these sheets shall be heatbonded or seamed for effective permeation cut off, at site using standard equipment as part of the laying process. While fixing on to a slope, they shall not be punctured or stappled to impair their use.

701.2.5 **Geocomposite** : Geocomposites shall be made from combination of geonets, geogrids or geomembranes of above description using heat bonded, seamed stitched or wrap techniques. Their principal use shall be to regulate drainage in cross-plane or in-plane directions. Minimum unit weight of such material shall conform to the special provisions or as per Contract drawing. Prefabricated Vertical Drains (PVDs)/ Band Drains are a Geocomposite and they are widely used to accelerate the consolidation of soft soil. The minimum required specifications for the same are given below:

Prefabricated vertical drains are made of geosynthetic materials. It consists of filter jacket surrounding a plastic core. The filter jacket or sleeve material consists of non woven geotextile made of polyester or polypropylene. The plastic core performs two vital functions i.e., it supports the filter jacket and it also provides path along the drain even at high lateral pressure. The PVDs should meet the following requirements to sustain the stresses during installation and to have compatibility of filter with the soil to be improved.

Physical requirements:

Weight e” 90 gm/sq. m, Width e” 90 mm and Thickness e” 5mm

Filter criterion requirement: The two key parameters that indicate the quality of filter are AOS (Apparent opening size) and cross plane permeability of filter. It is recommended that the following criteria be adopted for selection of PVDs.

O_{95} d” (2-3) D_{85} and O_{50} d” (10-12) D_{50}

Where O_{95} is AOS of filter, O_{50} is size that is larger than 50% of fabric pores, D_{85} and D_{50} refer to sizes of 85 percent and 50 percent of passing of soil particles by weight.

Permeability Requirement : The permeability of filter is normally required to be at least one order of magnitude higher than that of soil. The PVDs are generally used to accelerate the consolidation of very soft saturated soils such as marine clay. The permeability of such

soils found in India generally have permeability of the order of 10^{-7} to 10^{-10} m/s. Considering the clogging effect, a much higher permeability is required. To avoid clogging it is recommended that the permeability of PVDs should at least be of the order of 10^{-4} m/s.

701.2.6 Testing, handling, certification and acceptance : Geosynthetics shall be tested in accordance with tests prescribed by ASTM/ BIS for respective applications. In absence of ASTM/BIS Codes, tests prescribed either by British Standards or International Standards Organisation, shall be conducted. The supplier of the geotextile should provide to the Engineer, a certificate stating the name of the manufacturer, product name, style number, roll number, chemical composition of the filaments or yarns and other pertinent information regarding property values of individual roll to fully describe the geosynthetics.

The manufacturer is responsible for establishing and maintaining a quality control programme to assure compliance with the requirements of the specifications. Documentation describing the quality control programme shall be made available upon request. The manufacturer certificate shall state that the furnished geotextile meets MARV requirements of the specifications as evaluated under the Manufacturer's quality control programme and are in conformance as per ASTM D 4759. The certificate shall be attested by a person having legal authority to bind the manufacturer.

702.2.6.1 Handling and Storage of Geosynthetics

Geosynthetics must be handled and stored properly to ensure that the specified physical properties are retained to serve project needs. Geosynthetics rolls shall be furnished with suitable wrapping for protection against moisture, and extended ultraviolet exposure to ultraviolet exposure prior to placement. Each roll should be labeled or tagged to provide product identification sufficient for inventory and quality control purposes. Rolls should be stored in manner which protects them for elements. If stored outdoors, they shall be elevated and protected with water proof cover.The damages caused on this account can significantly reduce the geosynthetics ability to perform its intended function in some applications.

The objective of geosynthetics handling and storage is to safely transport and store the geotextile rolls at the project site without damaging the geosynthetics or unduly exposing it to sun light (ultraviolet light), moisture or other contamination. The following are some of the general recommendations to be followed while working with geosynthetics at site.

Site Handling

Rolls of geosynthetics should always be lifted off the ground surface prior to moving. Dragging the geosynthetics and operating equipment on the geosynthetics, which results in physical damage, shall be avoided at all times.

Site Storage

The geosynthetics rolls shall be adequately protected from ultraviolet light exposure during storage on site. A protective wrapping shall be kept on rolls until the geosynthetics are installed. If stored outside, the geotextile should be elevated from the ground surface and adequately covered to protect them from site construction damage, precipitation, ultraviolet radiation including sun light, chemicals that are strong acid/bases, flames including welding sparks, temperature in excess of 71^0C and any other environmental condition that may damage the geotextile.

Steps to be taken if geotextile roll or protective wrapping is damaged

In most cases, damage to a roll of geotextile is limited to the protective wrapping. If the wrapping is damaged, proper storage of the geotextile is particularly critical. The rolls must be elevated off the ground surface and securely covered with a tarpaulin or opaque plastic sheet. If the outer layer of the geotextile itself is damaged, it is permissible during installation to remove the outermost wraps of the roll and discard the damaged material. The remaining undamaged material is suitable for use. Removing the outermost wrap of geotextile is also acceptable when a roll is exposed to sunlight for a period beyond that permitted by the project specifications. The remaining unexposed material is suitable for construction. Exposing geotextile rolls to moisture or water prior to installation can lead to serious handling problems. Non-woven geotextiles in particular can absorb water upto three times their weight. Further, the cores on which the geotextile rolls are wound are manufactured from laminated paper. When wet, the strength of these cores is seriously diminished to the point where the core will not support the weight of the geotextile. Consequently, it can be extremely difficult to install wet rolls of geotextile. In addition, it is nearly impossible to unroll wet, frozen geotextile without first allowing it to thaw. If geotextile rolls become wet, it is permissible to remove the waterproof cover to allow for a few days of exposure to wind in order to dry the fabric. It is essential that the rolls be elevated during the process. It is also possible to remove the protective wrapping from one end of the roll and elevate the opposite end of the roll. The majority of excess water will then flow out of the geotextile. In most cases, these procedures will not allow the fabric to dry completely. Once unrolled during installation, the geotextile will dry very quickly in the sun and wind. However, it should be noted that non-woven geotextiles used in conjunction with bitumen overlays of existing pavements must be completely dry prior to installation.

702 GEOTEXTILES IN SUB-SURFACE DRAINS

702.1 Scope

This work shall consist of furnishing and placing a geotextile for the following drainage applications: edge of pavement drains; interceptor drains; wall drains; recharge basins, and relief wells. The geotextile shall be designed to allow passage of water while retaining

in-situ soil without clogging. The work shall be carried out as per design drawings. The quantities of drainage Geotextiles as shown on the plans may be increased or decreased at the direction of the Engineer based on construction procedures and actual site conditions that occur during construction of project. Such variations in quantity will not be considered as alternatives in the details of construction or a change in the character of the work.

702.2 Materials

The geotextile fabric shall be a woven or non-woven fabric consisting of long-chain polymeric filaments or yarns such as polypropylene, polyethylene or polyester or any combination thereof, formed into a stable network such that the filaments or yarns retain their relative position to each other. These materials shall conform to the physical requirements of Table 700-3.

All numeric values in Table 700-3 except AOS represent MARV in the weaker principal direction. Footnote of this Table 700-3 provides for a reduction in minimum property requirements when sufficient survivability information is available. The Engineer may also specify properties different from those listed in Table 2 based on engineering design and field experience.

Table 700-3 Geotextile Requirements for Subsurface Drainage

Per cent in-situ soil passing 0.075 mm sieve	Geotextile drainage property requirement		Recommended geotextile *
	Permittivity, per sec ASTM D 4491 (Minimum ARV)	Apparent opening size, mm ASTM D 4751 (Maximum ARV)	
< 15	0.5	0.43	Type II from Table 700-1
15 to 50	0.2	0.25	
> 50	0.1	0.22	

Note 1) In subsurface drainage, installation conditions are generally not very severe and hence geotextile Type II from Table 700-1 is recommended. However, the Engineer may specify Type III geotextile for trench drain applications on one or more of the following conditions :

a) The Engineer has found Type III geotextiles to have sufficient survivability on field experience.

b) Subsurface drain depth is less than 2 m; and drain aggregate diameter is less than 30 mm and compaction requirement is less than 95 per cent of Proctor density as per IS 2720: Part – 7.

2) Site specific geotextile design should be performed especially if one or more of the following problematic soil environments are encountered :

   Unstable or highly erodible soils such as non cohesive silts, gap graded soils, dispersive clays, etc.

3) A nominal coefficient of permeability may be determined by multiplying permittivity value by a nominal thickness. The K value of fabric should be greater than the K value of soil. Recommended Permittivity values for different soils are given below in Table 700-4.

Table 700-4 Recommended Permittivity for Different Soils

Soil type	Typical Range of Soil Permeability, Ks (cm/sec)	Minimum Recommended Geotextile Filter Permittivity, Y (per second)
Sandy Gravel	1×10^{-1} to 1×10^{-2}	0.5 to 0.1
Clean Sand	1×10^{-2} to 1×10^{-3}	0.1 to 0.01
Silty Sand	1×10^{-3} to 1×10^{-4}	0.01
Silt	1×10^{-4} to 1×10^{-5}	0.01
Clay	1×10^{-5}	0.01

702.3 Construction Requirements

Geotextile exposure following placement – Exposure of geotextiles to the elements between lay down and cover shall be a maximum of 14 days to minimize damage potential.

Geotextle Placement – In trenches, after placing the backfill material, the geotextile shall be folded over the top of the filter matieral to produce a minimum overlap of 30cm for trenches greater than 30cm wide. In trenches less than 30 cm wide, the overlap shall be equal to the width of the trench. The geotextile shall then be covered with the subsequent course.

Successive sheets of geotextiles shall be overlapped a minimum of 30 cm in the direction of flow.

Seams – Where seams are required in the longitudinal trench direction, they shall be joined by either sewing or overlapping. All seams shall be subject to the approval of the Engineer. Over seams shall have a minimum overlap equal to the width of the trench.

Repair – A geotextile patch shall be placed over the damaged area and extend 1m beyond the perimeter of the tear or damage.

702.4 Measurement for Payment

The geotextile shall be measured by the number of square metres computed from the payment lines shown on the plans with no allowance for overlapping at transverse and longitudinal joints or from payment lines established in writing by the Engineer. This excludes seam overlaps.excavation, backfill, bedding, and cover material which would be covered as per relevant clauses of these Specifications.

702.5 Rates

The contract unit rate for the accepted quantities of geotextile in place shall be per square.

Geotextile will be measured by square metre of roadway placement as shown in the plans. The rate will be is full compensation for furnishing, preparing, hauling, and placing materials including all labour, material, freight, tools, equipment, and incidentals to complete the work to these Specifications.

703 USE OF GEOSYNTHETICS IN COMPOSITE DRAINS

703.1 Scope

The work covers the use of geotextiles in subsurface drains, such as fin drains or narrow filter drains. The fin drain shall mean a planar geocomposite structure designed to perform the same function as a narrow filter drain. The work shall be carried out as per design drawings or as directed by the Engineer.

703.2 Materials

703.2.1 The geotextile fabric shall be a woven or non-woven fabric consisting of long-chain polymeric filaments or yarns such as polypropylene, polyethylene or polyester or any combination thereof, formed into a stable network such that the filaments or yarns retain their relative position to each other. These materials shall conform to the physical requirements of Table 7003-2.

703.2.2 The geosynthetic material of which the drain is made shall be treated with carbon black so that they are protected from the deleterious effects of short term exposure to ultraviolet light, and shall be resistant to degradation by acid, alkalis, common chemicals, bacteria, fungi and moulds occurring in soils highway construction materials. In case of exposure to ultraviolet light, the Engineer may require evidence that the geosynthetic material

still complies with the requirements of this Clause. Where necessary, the side intended for entry of water and direction of in-plane flow shall be identified.

703.2.3 The geotextile shall :

a) Sustain a load of not less than 10 kN/m at break and have a minimum failure strain of 10 per cent when determined in accordance with BS:6906 (Part 1) or shall have a grab tensile strength more than 0.4 kN/m and grab elongation corresponding to this limit in accordance with ASTM D4631.

b) The apparent opening size *@ shall satisfy the following :

Test Method	**Unis**	**Requirements Percent in-situ soil passing 0.075 mm**		
		<15	15 to 50	>50
ASTM D 4751	mm	0.43	0.25	0.22**

* These default filtration property values are based on the predominant particle size of in-situ soil. In addition to the default permittivity value, the Engineer may require geotextile permeability and/or performance testing based on engineering design for drainage systems in problematic soil environments.

@ Site-specific geotextile design should be performed especially if one or more of the following problematic soil environments are encountered; unstable or highly erodible soils such as non-cohesive silts; gap graded soils; alternating sand/silt laminated soils, dispersive clays; and/or rock flour.

** For cohesive soils with a plasticity index greater than 7 geotestile maximum average roll values for apparent opening size is 0.30 mm.

c) allow water to flow through it at right angles to its principal plane, in either direction at a rate of not less than 10 litres/m²/sec. under a constant head of water of 10 mm, determined in accordance with BS:6906 (Part 3) or ASTM D4491 or as stated in the design drawing. The flow rate determined in the test shall be corrected to that applicable to a temperature of 15°C using published data on variation iin viscosity of water with temperature.

d) have a minimum puncture resistance of 200 N when determined in accordance with BS:6906 (Part 4) or ASTM D 4833.

e) have a minimum tear resistance of 150 N when determined in accordance with ASTM Standard D 4533.

703.2.4 The composite drain shall have flow rate through each face of the drain of more than 75 per cent of the value specified in sub-Clause 702.2.3.(c), determined by direct measurement of the composite drain using BS:6906 (Part 3). The composite drain shall have values of long-term in-plane flow rates as stated in the design

703.3 Installation

The installation of fin drains shall be as per the design drawings. Where fin drains are assembled on site, the assembly area shall be clean and dry and free of any wind-borne pollutants. No geotextile or core material shall be exposed to daylight (or any source of ultraviolet radiation) for a period exceeding a cumulative total of 50 hours. Where fin drains are laid in trench, the bottom of the trench shall be free of irregularities and shall be brought to the required level. Rock and other hard protrusions shall be removed and any excess cut in the trench bottom filled and compacted back to the required grade with suitable excavated or imported material as directed by the Engineer. Fin drains shall be capable of being jointed longitudinal or laterally into pipe systems or chambers for inflow and outflow purposes. Joints parallel to the direction of flow and any exposed edge shall be protected from the ingress of soil by a geotextile wrapping with a minimum overlap of 150 mm or other measures as agreed by the Engineer.

703.4 Narrow filter drains consisting of a porous or perforated pipe and in a narrow trench surrounded by a layer of geotextile filter shall have the same properties of geotextile as specified in Clause 703.2. The spicing of lengths of geotextile and minimum overlap shall be as per the design drawing or as approved by the Engineer. Such drains shall be installed as per the design drawing to Clauses 703.3 and 309.3.5.

703.5 Measurement for Payment

Measurement for fin drain/narrow filter drains shall be per running metre length of the drain.

703.6 Rate

The Contract unit rates for subsurface drains shall be payment in full for all items such as excavation, dressing the sides and bottom, providing geotextile composites, laying and jointing pipes etc. including full compensation for all materials, labour, tools equipment incidental to complete the work as shown on drawings with all leads and lifts including removal of unsuitable material. Provision of inlets, outlet pipes, bedding, etc., wherever required shall be incidental to construction of drain.

704 GEOTEXTILES FOR EROSION CONTROL

704.1 Scope

This work shall consist of furnishing and placing a geotextile for erosion control application's such as cut and fill slope protection, protection of various small drainage structures and

ditches, wave protection for causeways and shore line roadway embankments, and scour protection for structures (bridge piers and abutments). The geotextile shall be designed to allow passage of water while retaining in situ soil without clogging. The quantities of erosion control geotextiles as shown on the plans maybe increased or decreased at the direction of the Engineer based on construction procedure and actual site conditions that occur during construction of the project. Such variations in quantity will not be considered as alterations in the details of construction or a change in the character of the wok.

704.2 Materials

704.2.1 Fibers used in the manufacture of geotextile, and the threads used in joining geotextiles by sewing, shall consist of long-chain synthetic polymers, composed of at least 85% by weight polyolefins, polyesters, or polyamides. They shall be formed into a network such that the filaments or yarns retain dimensional stability relative to each other, including selvedges. These materials shall conform to the physical requirements of Table 700-5

Table 700-5 Erosion Control Geotextile Requirements

Percent in-situ soil passing 0.075 mm sieve	Geotextile drainage property requirement		Recommended geotextile *
	Permitivity, per sec ASTM D 4491 Min ARV	Apparent opening size, mm ASTM D 4751Max ARV	
< 15	0.7	0.43	Type I from Table 700-1
15 to 50	0.2	0.25	
> 50	0.1	0.22	

704.2.2 Geotextile rolls shall be furnished with suitable wrapping for protection against moisture, and extended ultraviolet exposure prior to placement. Each roll shall be labeled or tagged to provide product identification sufficient for inventory and quality control purposes. Rolls shall be stored in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover.

704.3 Construction Requirements

704.3.1 **Geotextile Exposure Following Placement** – The geotextile shall be placed and anchored on a smooth graded surface approved by the Engineer. The geotextile shall be placed in such a manner that placement of the overlying materials will not excessively stretch or tear the fabric. Anchoring of the terminal ends of the geotextiles shall be accomplished through the use of key trenches or aprons at the crest and toe of slope.

(In certain applications to expedite construction, about 40 cm long anchoring pins placed on 1-3 m centers depending on the slope of the covered area have been used successfully).

704.3.2 Slope protection placement : Successive geotextile sheets shall be overlapped in such a manner that the upstream sheet is placed over the downstream sheet and/or upslope over down slope. In underwater application, the geotextile and required thickness of backfill material shall be placed the same day. The backfill placement shall begin at the toe and proceed up the slope. Riprap and heavy stone shall not be dropped onto the geotextile from the height of more than 30cm. Slope protection and smaller sizes of stone filling shall not be dropped onto the geotextile from the height exceeding 1m. Any geotextile damaged during placement shall be replaced as directed by the Engineer at Contractor's cost.

704.3.3 Seams : The geotextile shall be joined by either sewing or overlapping. All seams shall be subject to the approval of the Engineer. Overlapped seams shall be a minimum overlap of 30 cm. except where placed under water where the overlap shall be a minimum of 1 m.

704.3.4 Repair : A geotextile patch shall be placed over the damaged area and extend 1m beyond the perimeter of the tear or damage.

704.4 Measurement for Payments

The geotextile shall be measured by the number of square metres computed from the payment lines shown on the plans with no allowance for overlapping at transverse and longitudinal joints or from payment lines established in writing by the Engineer. This excludes seam overlaps, but shall include geotextiles used in crest and toe of slope treatments, slope preparation, excavation and backfill, bedding, and cover material which would be covered as per relevant clauses of these Specifications.

704.5 Rates

The contract uit rate for the accepted quantities of geotextile in place shall be per square.

The rate is full compensation for furnishing, preparing, hauling, and placing materials including all labour, material, freight, tools, equipment, and incidentals to complete the work to these Specifications.

705 GEOGRID APPLICATIONS FOR REINFORCED SOIL SLOPE PROTECTION

705.1 Description : This work shall consist of constructing a reinforced soil slope in accordance with the contract documents and as directed by the Engineer. The Contractor

shall provide all labour, equipment, and materials for and incidental to site preparation, furnishing, installing, and backfilling geogrid reinforcement as indicated.

705.2 Material

Geogrid reinforcement : The geogrid reinforcement for primary slope stabilization shall be uniaxially oriented grid structure. The geogrid reinforcement for secondary slope stabilization shall be a biaxially oriented grid structure. The manufacturer shall furnish the Engineer with test reports certifying that the product meets the requirements of these Specifications. Un-iaxail and bi-axaial geogrid shall be regular grid structure. The geogrid shall have high resistance to deformation under sustained long-term design load while in service and shall be resistant to ultraviolet degradation, damage under normal construction practices and all forms of biological or chemical degradation normally encountered in the material being reinforced. The long term allowable tensile strength shall have the minimum value of 156.6 kN/m. The minimum pull-out resistance factor shall be 0.42 as determined by ASTM D 6706.

Backfill : The contractor shall provide select granular backfill material as per contract.

Facing : The contractor shall provide stone fill and geotextile as facing for the reinforced soil slope to the lines and grades shown on the plans.

705.3 Installation

All areas immediately beneath the installation area for the geogrid shall be properly prepared as detailed on the plans and as per these Specifications or as directed by the Engineer.

The geogrid shall be installed in accordance with the manufacturere's recommendation. The geogrid shall be placed within the layers of the compacted soil as shown on the plans or as directed by the Engineer. If the contractor is unable to complete a required length with a single continuous length of geogrid a joint may be made with the approval of the Engineer. After the specified layer has been placed in its entirety and compacted, the next geogrid layer shall be installed in its entirety. The process shall be repeated for such subsequent layer of geogrid and soil. Geogrid reinforcement shall be placed to lay flat and pulled tight prior to backfilling . After a layer of geogrid has been placed , suitable means, such as pins or small piles of soil shall be used to hold geogrid in position until the subsequent soil layer can be placed. Under no circumstances shall a track type vehicle be allowed on the geogrid before at least 150mm of soil has been placed.

Backfill placement : Backfill shall be compacted as specified by project specifications or at least 95 percent of the maximum density determined in accordance with IS:2726 (Part-8), whichever is greater. Backfill within 900 mm of slope face shall typically be compacted with hand equipment. Fill shall be placed in 200 mm maximum lift thickness.

705.4 Measurement and basis of payment : The quantity of special provision to be measured for payment will the number of square meters of geogrid installed in the complete and accepted work.

705.5 Rates

The Contract unit rate will be full compensation for furnishing and installing the specified materials in accordance with the contract documents including on-site supplier representation, site preparation, geosynthetics reinforcement and backfill and for furnishing all labor, tools equipment and incidentals necessary to complete the work to these Specification.

706 GEOSYNTHETICS FOR HIGHWAY PAVEMENTS

706.1 Scope

This work shall consist of furnishing and placing geogrid over existing subbgade or subbase or within the base layer in accordance with the lines and grades shown on the plans or as directed by the Engineer. Base/Sub base reinforcement in properly designed paved roads, occur when a geogrid is placed at the subgrade/subbase interface to provide improved subgrade support for the roadway structural section; to extend the service life of flexible pavement and/or; to allow the use of a reduced base section. The selection of the type of geogrid and its strength characteristics shall depend upon the design of pavement with geogrid reinforced highway pavements.

706.2 Materials

Polymers used in the manufacture of geogrids shall consist of long-chain synthetic polymers, composed of at least 95 per cent by weight of polyolefins, polyesters or polyamides. They shall be formed into a stable network such that ribs, filaments or yarns retain their dimensional stability relative to each other including selvages. The aperture size of geogrid may vary from 25 mm to 50 mm. The per cent open area of the geogrid shall be minimum 70 percent. The following specifications may be used for Geogrid for use as reinforcement of base or sub base layers of flexible pavement structures. The values given in Table 700-6 are default values sufficient from survivability point of view. However, the designer may specify values other than specified based on design.

706.3 Certification

The Contractor shall provide the Engineer, a certificate stating the name of manufacturer, product name, style number, chemical composition of the product and other pertinent information to fully describe the geogrid. The certificate shall state that the furnished geogrid meets MARV requirements of the specifications as evaluated under the manufacturer's quality control program. The certification shall be attested by a person having legal authority to bind the manufacturer.

Table 700-6 Requirements for Geogrid for Sub-Base/Base of Flexible Pavements

Property	Test Method	Required value,kN/m	
		Machine Direction	Cross Direction
Tensile strength@1% strain	ASTM D6637	4.3	6.6
Tensile strength@2% strain	ASTM D6637	7.3	10.9
Tensile strength@5% strain	ASTM D6637	13.4	19.7
Tensile modulus @5% strain	ASTM D6637	437	656
Junction Efficiency, % of rib ultimate tensile strength		90	90
Ultraviolet stability (after 500 hrs)	ASTM D4355	70%	

Note 1) All numerical values in the Table represent MARV in the specified direction.

2) All geogrids shall be placed along machine direction parallel to the centre line of roadway alignment.

3) Junction strength is required to maintain dimensional stability of the geogrid during deployment. It is not applicable to geogrid/geotextile composite products.

706.4 Installation

All areas immediately beneath the installation area for the geogrid shall be properly prepared as detailed on the plan and, as per these Specifications or as directed by the Engineer.

The geogrid shall be installed in accordance with the manufacturere's recommendation. The geogrid shall be placed within the layers of the compacted soil as shown on the plans or as directed by the Engineer. If the Contractor is unable to complete a required length with a single continuous length of geogrid, a joint may be made with the approval of the Engineer. Geogrid reinforcement shall be placed to lay flat and pulled tight prior to backfilling . After a layer of geogrid has been placed , suitable means, such as pins shall be used to hold geogrid in position until the subsequent soil layer can be placed. Under no

circumstances shall a track type vehicle be allowed on the geogrid before at least 150mm of soil has been placed.

706.5 Measurement for Payment

Geogrid will be measured by square metre of roadway placement as shown in the plans with no allowance for overlapping at transverse and longitudinal joints.

706.6 Rate

The Contract unit rate will be for geogrid for subbase or base. The rate is full compensation for the work performed and furnishing, preparing, hauling, and placing materials including all labour, material, freight, tools, equipment, and incidentals to complete the work to these Specifications.

707 GEOSYNTHETICS OVER EXISTING BITUMENOUS SURFACE

707.1 Scope

This work shall consist of laying geosynthetic materials over existing bituminous surface, including preparation of surface and joining, stitching or overlapping of geosynthetic fabric etc., as part of highway pavement strengthening in layers as shown on drawings or as directed by the Engineer.

707.2 Paving Fabrics

707.2.1 Description : This work shall consist of furnishing and placing as asphalt/ bitumen overlay textile (paving fabric) beneath a pavement overlay or between pavement layers to provide a water resistant membrane and crack retarding layer.

707.2.2 Material Requirements

The paving fabric will be a nonwoven heat set material consisting of at least 85 per cent by weight of polyolefins, polyesters or polyamides. The paving fabric shall be resistant to chemical attack, rot and mildew and shall have no tears or defects which will adversely alter its physical properties. The fabric shall be specifically designed for pavement applications and be heat bonded only on one side to reduce bleed-through of tack coat during installation. The fabric shall meet the physical requirements given in Table 700-7. Heavy duty paving fabrics should be used in areas experiencing unusually high impact forces or heavy loads such as airport runways and taxiways.

Table 700-7. Physical Requirements for Paving Fabrics

Property	Units	Standard Requirements	Test Method
Tensile Strength	Kg	36.3	ASTM D 4632
Elongation	%	50	ASTM D 4632
Asphalt Retention	Kg/10 sq.m.	10	Texas DOT 3099
Melting Point	°C	150	ASTM D 276
Surface Texture	-	Heat bonded on One side only	Visual Inspection

Notes: 1. Certification of conformance from paving fabric manufacturer shall be required.

2. All numerical values represent minimum average roll values (average of test results from any sampled roll in a lot shall meet or exceed the minimum values) in weaker principal direction. Lot shall be sampled according to ASTM D 4354, "Practice for Sampling of Geosynthetics for Testing".

3. Conformance of paving fabrics to specification property requirements shall be determined as per ASTM D 4579. "Practice for Determining the Specification Conformance of Geosynthetics".

707.2.3 **Tack coat** : The tack coat used to impregnate the fabric and bond the fabric to the pavement shall be paving grade Bitumen of 80-100 penetration. A cationic or anionic emulsion may be used as approved by the Engineer. The cutbacks or emulsions which contain solvents shall not be used.

707.2.4 Construction and Installation Requirements

707.2.4.1 **Shipment and storage :** The paving fabric shall be kept dry and wrapped such that it is protected from the elements during shipping and storage. At no time shall the paving fabric be exposed to ultraviolet light for a period exceeding fourteen days. Paving fabric rolls shall be stored in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover. The paving fabric shall be labeled as per ASTM D 4873, "Guide for identification, storage, and handling of geotextiles".

707.2.4.2 **Weather limitations :** Minimum air and pavement temperature shall be at least 10°C and rising for placement of bitumen and shall be atleast 15°C and rising for placement bitumen emulsion. Neither bitumen tack nor paving fabric shall be placed when weather conditions, in the opinion of the Engineer, are not suitable.

707.2.4.3 Surface preparation : The pavement surface shall be thoroughly cleaned of all dirt, water, and oil to the satisfaction of the Engineer. Cracks 3 mm wide or greater shall be cleaned and filled with suitable bituminous material or by a method approved by the Engineer. Crack filling material shall be allowed to cure prior to paving fabric placement. Potholes and other pavement distress shall be repaired. Repairs shall be carried out as directed by the Engineer. If the condition of the existing pavement is such that a simple crack fill operation is not adequate for surface preparation, then a levelling course may be provided prior to placing the fabric.

707.2.4.4 Tack coat application : The tack coat shall be spread by means of a calibrated distributor spray bar. Hand spraying and brush application may be used in locations of fabric overlap. Every effort shall be made to keep hand spraying to a minimum. The tack coat shall be applied, uniformly to the prepared dry pavement surface at the rate of 1 kg/sq.m or as recommended by the paving fabric manufacturer and approved by the Engineer. Rough and raveled surfaces may require a higher application rate. When using emulsions, the application rate must be increased as directed by the Engineer to offset the water content of the emulsion. Within street intersections, or steep grades, or in other zones where vehicle speed changes are common place, the normal application rate shall be reduced by about 20 percent as directed by the Engineer. The tack coat application rate must be sufficient to saturate the fabric and to bond the fabric to the existing pavement surface.

The temperature of the tack coat shall be sufficiently high to permit a uniform spray pattern. For bitumen, the minimum temperature shall be 140°C. To avoid damage to the fabric, distributor tank temperature shall not exceed 160°C. For bitumen emulsions, the distributor tank temperature shall be maintained between 55°C and 70°C.

The target width of tack coat application shall be equal to the paving fabric width plus 150 mm. The tack coat shall be applied only as far in advance of paving fabric installation as is appropriate to ensure a tacky surface at the time of paving fabric placement. Traffic shall not be allowed on the tack coat. Excess tack coat shall be cleaned from the pavement.

707.2.4.5 Paving fabric placement : The paving fabric shall be placed onto the tack coat using mechanical or manual lay down equipment capable of providing a smooth installation with a minimum amount of wrinkling or folding. The paving fabric shall be placed prior to the tack coat cooling and losing tackiness. After laying the paving fabric, some loose bituminous concrete should be sprinkled on it in the wheel path of the paver and the tipper to ensure that the fabric is not picked up between the wheels. Paving fabric shall not be installed in areas where the overlay asphalt tapers to a thickness of less than 40 mm. Excess paving fabric which extends beyond the edge of existing pavement or areas of tack coat application shall be trimmed and removed. When bitumen emulsions are used, the emulsion shall be allowed to cure properly such that essentially no water moisture

remains prior to placing the paving fabric. Wrinkles or folds in excess of 25 mm shall be shingle-lapped in the direction of the paving operation. Brooming and/or pneumatic rolling will be required to maximize paving fabric contact with the pavement surface. Additional hand-placed tack coat may be required at laps and repairs as determined by the Engineer to satisfy bitumen retention of the lapped paving fabric. All areas with paving fabrics placed will be paved the same day. No traffic except necessary construction equipment will be allowed to drive on the paving fabric.

Turning of the paver and other vehicles shall be done gradually and kept to a minimum to avoid movement and damage to the paving fabric. Abrupt starts and stops shall also be avoided. Damaged fabric shall be removed and replaced with the same type of fabric. Overlaps shall be shingle-lapped in the direction of paving. Additional tack coat shall be placed between the overlap to satisfy saturation requirements of the fabric. Overlap shall be sufficient to ensure full closure of the joint but not exceed 150m.

707.2.4.6 Overlay placement : Bituminous overlay construction shall closely follow fabric placement. All areas in which paving fabric has been placed will be paved during the same day. Excess tack coat which bleeds through the paving fabric shall be removed. Excess tack coat can be removed by broadcasting hot mix or sand on the paving fabric.

707.2.5 Measurement for Payment

Paving fabric will be measured in square meters as shown on the plans with the allowance for overlapping at joints.

707.2.6 Rate

The contract unit rate shall be for the accepted quantities of paving fabric. The rate is full compensation for the work performed and furnishing, preparing, hauling and placing materials including all labour, material, freight, tools, equipment and incidentals to complete the work to these Specifications.

708 PROTECTION WORKS WITH GEOSYNTHETICS

708.1 Scope

This work shall consist of laying boulder Gabions/Mattresses in wraps of Geosynthetics in the form of bolsters, on slopes of embankments or in aprons. Gabions or Mattresses are also used for stone spurs. Geotextiles are used for prevention of migration of fine soil particles.

708.2 Gabions/Mattresses with Geogrids and Geonets

Mattresses constructed with Geogrids or Geonets shall be used for thickness of 30 mm or above as shown in the drawings. While adopting a particular size for gabions or mattresses, width of the roll of geogrid/geonet may be kept in view to minimize wastage of the geosynthetic in cutting off pieces. The mesh opening may vary depending on functional requirement but shall have aperture between 35 mm and 100 mm. The mesh/net shall have following characteristics:

Aperture	:	Rectangular, square or oval shaped (and not in diamond, round or polygonal shape).
Colour	:	Black
Mechanical Properties	:	Peak strength not less than 10 kN/m at maximum elongation of 15 per cent. Not more than 5 per cent elongation at half peak load.
Stands/Fabric Form	:	Integral joints with junction strength of 100 per cent of plain strands as measured by GRI-GG3 standards. Material shall have ISO 9002 certification.
Life	:	Atleast 8 years in case of continuous exposure and 5 years for buried applications (defined as capable of retaining atleast 75 per cent of its original strength after the life span stated).

708.3 Construction

708.3.1 Assembly : Gabion and mattress boxes shall be assembled in situ, on a level surface. After fabrication is done in situ, they shall be correctly filled in layers in dense packed state.

The bottom, sides and end panels shall be erected after removal of all kinds, kept in an upright position to form rectangular boxes by joining the sides with connectors of 40 mm x 6 mm size, or by ring staples. The top corners shall be tie tensioned from sides to keep it erect for filling. For gabions of 600 mm or more height, suitable cross internal ties shall be placed in layers of 300 mm connecting opposite sides in lateral braces tied with polymer braids of ultra-violet stabilized variety so as to ensure protection against bulging of the gabions during filling with stones.

708.3.2 Construction and installation : The filling of the gabion/mattress shall be done by hand in layers so as to minimize voids and achieve specified density. The stones in contact with the surface of the geogrids/geonets shall be placed in such a way that their

sharp edges are kept turned inside so that they do not damage the material of the geogrids/ geonets. The opposite panels of the boxes shall be firmly secured with lateral ties to withstand the design forces. The bottom of the gabion mesh shall be secured in a key type excavation for preventing slide. The space between the gabion and earthen sides shall be filled with sand and the filling compacted. In most of the cases design shall be supplemented with a layer of geotextile under the gabion/mattress to prevent migration of fines.

708.3.3 Laying boulder apron in crates : Mattresses of minimum height 300 mm shall be used. The typical size of a single continuous unit shall be 1 m x 5 m size with baffles at 1 m centres. The size of boulders shall be least 100 mm or double the size of the aperture whichever is larger. The density of boulder filling shall be as stated in the drawing and the specific gravity of stones not less than 2.65. Methodology of laying boulders shall be as per Clause 2503.3. Gabions if placed in the apron shall be of size 1 m x 5 m in plan with height at least 600 mm, with baffles at 1 m centres.

Gabions or mattresses made with polymer geogrids/geonets shall always be laid in situ and shall not be preformed, filled and transported to be dropped in deep waters. Where depth of water is low or dry bed is available, the boxes shall be filled in situ. In streams or water body having running boulders in the bed, the gabions/mattresses shall be armoured with placement of loose large boulders alongside the gabion wall to protect against impact hit of stray boulders.

Stakes or keying shall always be provided in the founding recess, where the gabion, be located, especially in case the ground is assessed to be sloping or yielding type.

708.3.4 Groynes or spurs with crates : Groynes or spurs of gravity retaining variety shall be constructed using geogrid/geonet gabions placed in stable configuration one over the other to form a well. They shall be filled in situ on a shallow depth of water or dry bed with firm founding and level strata. The provision of a layer of geotextile/geocomposite shall be made while placing the structure if resting over a bed of fine soil to prevent passage of fines and sinking.

708.3.5 Measurement for payment : The fabric of geotextile/geocomposite shall be measured in sq.metres of plan area of actual use (as per drawing).

The connecting rods or polymer braids shall be measured in metres. Ring staples shall be measured in number provided per linear metre.

The boulder fill shall be measured in cubic metres.

The excavation for keying of gabions in the ground trenches shall be measured in cubic metres.

The backfilling in side trenches shall be deemed part of the excavation work.

708.3.6 Rate : The cost of Geosynthetic material for fabrication of Gabions/ Mattresses shall be all inclusive of supply, transportation and storage.

The contract rate per cubic metre of crate fill shall consist of cost of boulders and their transportation.

The contract rate for excavation including backfilling of trenches, seating trench upto 15 cm (included in rate), shall include cost of all labour, tools and plant for completion of the work to these Specifications.

The cost of making a crate shall include preparation of box of geogrid/geonet, tensioning and staking arrangements, tying, internal crossbraids, etc., for forming of the crates in an engineered manner and filling the crate by laying boulders. The cost shall include transportation of material from store to site.

Whenever composite system using Geosynthetics with natural material like stone revetment etc. shall be used, the provision of measurement and rate as per Clauses 2509 and 2510 are applicable.

800

Traffic Signs, Markings and Other Road Appurtenances

801 TRAFFIC SIGNS

801.1 General

801.1.1 The colour, configuration, size and location of all traffic signs for highways (other than Expressways for which the size of the signs, letters and their placement shall be as specified in the drawings and relevant Specifications or as directed by the Engineer) and for other roads, shall be in accordance with the Code of Practice for Road Signs, IRC:67:2001, or as shown on the drawings. In the absence of any details or for any missing details (for example, chevron signs etc.), the signs shall be provided in accordance with international standards and/or as directed by the Engineer.

801.1.2 Unless otherwise specified, the signs shall be reflectorised as shown on the drawings or as directed by the Engineer. They shall be of retro-reflectorised type and made of enclosed lens **/** encapsulated lens / micro-prismatic type reflective sheeting vide Clause 801.3, fixed over a substrate vide Clause 801.2.5 of these Specifications.

801.1.3 In general, cautionary and mandatory signs shall be fabricated through process of screen printing. In regard to informatory signs with inscriptions or cut letters of, coloured retroreflective sheeting comprising unmetalised microprismatic element material vide Clause 801.3 or durable transparent, coloured overlay film shall be used which must be bonded well on the base sheeting, as directed by the Engineer.

801.2 Materials

The various materials and fabrication of the traffic signs shall conform to the following requirements:

801.2.1 **Concrete :** Concrete shall be of the grade shown on the Contract drawing or otherwise as directed by the Engineer.

801.2.2 **Reinforcing steel :** Reinforcing steel shall conform to the requirement of IS:1786 unless otherwise shown on the drawing.

801.2.3 **Bolts, nuts, washers :** High strength bolts shall conform to IS:1367 whereas precision bolts, nuts, etc., shall conform to IS:1364.

801.2.4 **Plates and supports :** Plates and support sections for the sign posts shall conform to IS:226 and IS:2062 or any other relevant IS Specifications.

801.2.5. **Substrate :** Sign panels may be fabricated on aluminium sheet, aluminium composite panel, fibre glass sheeting, or sheet moulding compound**.** Aluminum sheets used for sign boards shall be of smooth, hard and corrosion resistant aluminium alloy conforming to IS:736-Material designation 24345 or 1900. Aluminium Composite Panel and other materials shall meet the relevant ASTM (D903, E8, E393, E732)/BS/BIS requirements.

801.2.6 Signs with a maximum side dimension not exceeding 600 mm shall not be less than 1.5 mm thick made of aluminium and shall not be less than 4 mm thick made out of other materials vide Clause 801.2.5. All others shall be at least 2 mm thick made of aluminium and shall not be less than 4 mm thick made out of other materials vide Clause 801.2.5. The thickness of the sheet shall be related to the size of the sign and its support and shall be such that it does not bend or deform under the prevailing wind and other loads.

801.2.7 In respect of sign sizes not covered by IRC:67, the structural details (thickness, etc.) shall be as per the approved drawings or as directed by the Engineer.

801.3 Traffic Signs having Retro-Reflective Sheeting

801.3.1 General requirements : The retro-reflective sheeting used on the sign shall consist of the white or coloured sheeting having a smooth outer surface which has the property of retro-reflection over its entire surface. It shall be weather-resistant and show colour fastness. It shall be new and unused and shall show no evidence of cracking, scaling, pitting, blistering, edge lifting or curling and shall have negligible shrinkage or expansion. A certificate of having tested the sheeting for co-efficient of retro-reflection, day/night time colour luminous, shrinkage, flexibility, linear removal, adhesion, impact resistance, specular gloss and fungus resistance and its having passed these tests shall be obtained from a Government Laboratory, by the manufacturer of the sheeting. The retro- reflective sheeting shall be either of Engineering Grade material with enclosed lens, High Intensity Grade with encapsulated lens or Micro-prismatic Grade retro-reflective element material as given in Clauses 801.3.2 to 801.3.7.

801.3.2 Engineering grade sheeting : This medium intensity retro reflective sheeting shall be typically enclosed lens glass-bead sheeting. Typical applications for this material are on Rural Roads The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (determined in accordance with ASTM Standard D: 4956-07) as indicated in Table 800-1**.**

Table 800-1 Acceptable Minimum Coefficient of Retro Reflection[A] for Engineering Grade Sheeting (Candelas Per Lux Per Square Metre)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.2°	-4°	70	50	25	9.0	14.5	4.0	1.0
0.2°	+30°	30	22	7	3.5	6.0	1.7	0.3
0.5°	-4°	30	25	13	4.5	7.5	2.0	0.3
0.5°	+30°	15	13	4	2.2	3.0	0.8	0.2

[A] Minimum Coefficient of Retro reflection (R_A) cd/fc/ft^2(cd-lx^{-1}.m^2).

When totally wet, the sheeting shall show not less than 90 percent of the values of retro-reflection indicated in Table 800-1. At the end of 5 years, the sheeting shall retain at least 50 percent of its original retro-reflectance.

801.3.3 Super engineering grade sheeting : This medium-high intensity retro reflective sheeting shall be typically enclosed lens glass-bead sheeting. Typical applications for this material are on Rural Roads. The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (determined in accordance with ASTM Standard D: 4956-07) as indicated in Table 800-2.

Table 800-2 Acceptable Minimum Coefficient of Retro-Reflection[A] for Super Engineering Grade Sheeting (Candelas Per Lux Per Square Metre)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.2^o	-4^o	140	100	60	30	30	10	5
0.2^o	$+30^o$	60	36	22	10	12	4	2
0.5^0	-4^o	50	33	20	9	10	3	2
0.5^o	$+30^o$	28	20	12	6	6	2	1

[A] Minimum Coefficient of Retro reflection (R_A) $cd/fc/ft^2(cd\text{-}lx^{-1}.m^{2})$.

When totally wet, the sheeting shall show not less than 90 percent of the values of retro-reflection indicated in Table 800-2. At the end of 5 years, the sheeting shall retain at least 65 percent of its original retro-reflectance.

801.3.4 High intensity grade : This high intensity retro reflective sheeting shall be of encapsulated lens type consisting of spherical glass lens, elements adhered to a synthetic resin and encapsulated by a flexible, transparent waterproof plastic having a smooth surface. Typical applications for this material are on Rural Roads and on Major District Roads The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (determined in accordance with ASTM Standard D: 4956-07) as indicated in Table 800-3.

801.3.5. High intensity micro-prismatic grade sheeting : This sheeting shall be of high intensity retro-reflective sheeting made of unmetallized micro-prismatic retro-reflective element material coated with pressure sensitive adhesive. Typical applications for this material are for traffic signs on National Highways and State Highways. The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (determined in accordance with ASTM Standard :D: 4956-07) as indicated in Table 800-4.

Table 800-3 Acceptable Minimum Coefficient of Retro-reflection for High Intensity Grade Sheeting (Encapsulated Lens Type) (Candelas Per Lux Per Square Metre)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown
0.1 ^{oB}	-4°	300	200	120	54	54	24	14
0.1^{oB}	+30°	180	120	72	32	32	14	10
0.2°	-4°	250	170	100	45	45	20	12
0.2°	+30°	150	100	60	25	25	11	8.5
0.5°	-4°	95	62	30	15	15	7.5	5.0
0.5°	+30°	65	45	25	10	10	5.0	3.5

[A] Minimum Coefficient of Retro reflection (R_A) cd/fc/ft^2(cd-lx^{-1}.m^2).
[B] Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

When totally wet, the sheeting shall show not less than 90 percent, of the values of retro-reflectance indicated in Table 800-3. At the end of 7 years, the sheeting shall retain at least 80 percent of its original retro-reflectance.

Table 800-4 Acceptable Minimum Coefficient of Retro-Reflection for High Intensity Micro-prismatic Grade Sheeting (Candelas Per Lux Per Square Metre)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Brown	Fluorescent Yellow -Green	Fluorescent Yellow	Fluorescent Orange
0.1 ^{oB}	-4°	500	380	200	70	90	42	25	400	300	150
0.1^{oB}	+30°	240	175	94	32	42	20	12	185	140	70
0.2°	-4°	360	270	145	50	65	30	18	290	220	105
0.2°	+30°	170	135	68	25	30	14	8.5	135	100	50
0.5°	-4°	150	110	60	21	27	13	7.5	120	90	45
0.5°	+30°	72	54	28	10	13	6	3.5	55	40	22

[A] Minimum Coefficient of Retro reflection (R_A) cd/fc/ft^2(cd-lx^{-1}.m^2).
[B] Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

When totally wet, the sheeting shall show not less than 90 percent of the values of retro-reflection indicated in Table 800-4. At the end of 7 years, the sheeting shall retain at least 80 percent of its original retro-reflectance.

801.3.6 Super high intensity micro-prismatic grade sheeting : This sheeting shall be of super high intensity retro-reflective sheeting made of unmetallized micro-

prismatic retro-reflective element material having highest retro reflectivity characteristics at long and medium road distances as determined by the R_A values of Table 800-5 at 0.1° and 0.2° observation angles. Typical applications for this material are cautionary, mandatory signs and for delineators. On National Highways and State Highways expressways and Urban Arterials. The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (determined in accordance with ASTM Standard : D: 4956-07) as indicated in Table 800-5.

Table 800-5 Acceptable Minimum Coefficient of Retro-reflection for Super High Intensity Micro-prismatic Grade Sheeting Type A (Candelas Per Lux Per Square Metre)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow -Green	Fluorescent Yellow	Fluorescent Orange
0.1 ^{oB}	-4°	1000	750	375	100	200	45	800	600	300
0.1^{oB}	+30°	570	430	215	57	115	26	460	340	170
0.2°	-4°	750	560	280	75	150	34	600	450	230
0.2°	+30°	430	320	160	43	86	20	340	260	130
0.5⁰	-4°	240	180	90	24	48	11	190	145	72
0.5°	+30°	135	100	50	14	27	6.0	110	81	41

^{A} Minimum Coefficient of Retro reflection (R_A) cd/fc/ft^2(cd-lx^{-1}.m^2).

^{B} Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

When totally wet, the sheeting shall show not less than 90 percent of the values of retro-reflection indicated in Table 800-5. At the end of 10 years, the sheeting shall retain at least 80 percent of its original retro-reflectance.

801.3.7 Very high intensity micro-prismatic grade sheeting : This sheeting shall be of very high intensity retro-reflective sheeting made of unmetallized micro-prismatic retro-reflective element material having highest retro-reflectivity characteristics at short road distances as determined by the R_A values of Table 800-6 at 0.1° and 0.2° observation angles. Typical applications for this material are for overhead signs on National Highways, State Highways, expressways and on Urban Arterials. The retro-reflective surface after cleaning with soap and water and in dry condition shall have the minimum co-efficient of retro-reflection (determined in accordance with ASTM Standard : D: 4956-07) as indicated in Table 800-6.

801.3.8 Messages/borders : The messages (legends, letters, numerals etc.) and borders shall either be screen-printed or of cut-outs from durable transparent overlay or cut-out from same type of reflective sheeting (excluding for black colour) for the cautionary/ mandatory signs. Screen printing shall be processed and finished with materials and in a manner specified by the sheeting manufacturer. For the information and other signs, the

messages (legends, letters, numerals etc.) and borders shall be cut-out from durable transparent overlay film or cut out from same reflective sheeting only. Cut-outs shall be bonded with the sheeting in the manner specified by the manufacturer. Both the screen printed areas and cut-out messages sheetings and cut-out durable transparent overlay film shall be covered under the warranty period of the sheeting type, issued by the sheeting manufacturer

Table 800-6 Acceptable Minimum Coefficient of Retro-reflection for Very High Intensity Micro-prismatic Grade Sheeting (Candelas Per Lux Per Square Metre)

Observation Angle	Entrance Angle	White	Yellow	Orange	Green	Red	Blue	Fluorescent Yellow -Green	Fluorescent Yellow	Fluorescent Orange
0.1 °B	-4°	660	500	250	66	130	30	530	400	200
0.1°B	+30°	370	280	140	37	74	17	300	220	110
0.2°	-4°	380	285	145	38	76	17	300	230	115
0.2°	+30°	215	162	82	22	43	10	170	130	65
0.5°	-4°	240	180	90	24	48	11	190	145	72
0.5°	+30°	135	100	50	14	27	6.0	110	81	41
1.0°	-4°	80	60	30	8.0	16	3.6	64	48	24
1.0°	+30°	45	34	17	4.5	9.0	2.0	36	27	14

[A] Minimum Coefficient of Retro reflection (R_A) cd/fc/ft^2(cd-lx^{-1}.m^2).

[B] Values for 0.1° observation angles are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

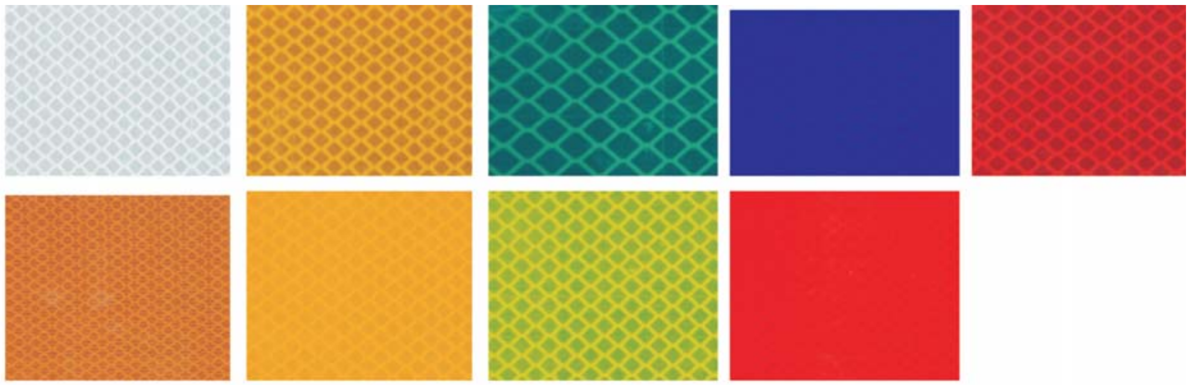
When totally wet, the sheeting shall show not less than 90 percent of the values, of retro-reflection indicated in Table 800-6. At the end of 10 years, the sheeting shall retain at least 80 percent of its original retro-reflectance.

801.3.9 For screen-printed transparent coloured areas on white sheeting, the co-efficient of retro-reflection shall not be less than 50 per cent of the values of corresponding colour in Tables 800-1, 800-2, 800-3, 800-4, 800-5 and 800-6, as applicable.

801.3.10 Cut-out messages and borders, wherever used, shall be made out of retro-reflective sheeting (as per Clauses 801.3.2/801.3.3/801.3.4/801.3.5/801.3.6/ 801.3.7) as applicable), except those in black which shall be of non-reflective sheeting.

801.3.11 **Colour :** Unless otherwise specified, the general colour scheme and properties shall be as stipulated in ASTM 4956–07. The colours shall be durable and uniform in acceptable hue when viewed in day light or under normal headlights at night and in inclement weather conditions. The indicative pictorial depiction is given in Table 800-7.

Table 800-7 Indicative Pictorial Depiction of Colours of Sheetings



801.3.12 Adhesives : The sheeting shall have either a pressure-sensitive adhesive of the aggressive-tack type requiring no heat, solvent or other preparation for adhesion to a smooth clean surface, or a tack free adhesive activated by heat, applied in a heat-vacuum applicator, in a manner recommended by the sheeting manufacturer. The adhesive shall be protected by an easily removable liner (removable by peeling without soaking in water or other solvent) and shall be suitable for the type of material of the base plate used for the sign. The adhesive shall form a durable bond to smooth, corrosion and weather resistant surface of the base plate such that it shall not be possible to remove the sheeting from the sign base in one piece by use of sharp instrument. In case of pressure-sensitive adhesive sheeting, the sheeting shall be applied in accordance with the manufacturer's Specifications. Sheeting with adhesives requiring use of solvents or other preparation for adhesive shall be applied strictly in accordance with the manufacturer's instructions.

801.3.13 Refurbishment : Where existing signs are specified for refurbishment, the sheeting shall have a semi-rigid aluminium backing or materials as per Clause 801.2.5, pre-coated with aggressive-tack type pressure sensitive adhesive. The adhesive shall be suitable for the type of material used for the sign and should thoroughly bond with that material.

801.3.14 Fabrication

801.3.14.1 Surface to be reflectorised shall be effectively prepared to receive the retro-reflective sheeting. The sheeting of the material as per Clause 801.2.5, shall be de-greased either by acid or hot alkaline etching and all scale/dust/ coating of any type removed/ scrubbed to obtain a smooth plain surface before the application of retro-reflective sheeting. If the surface is rough, approved surface primer may be used. After cleaning, metal shall not be handled, except by suitable device or clean canvas gloves, between all cleaning and preparation operation and application of reflective sheeting/primer. There shall be no opportunity for the substrate to come in contact with grease, oil or other contaminants prior to the application of retro-reflective sheeting.

801.3.14.2 Complete sheets of the material shall be used on the signs except where it is unavoidable; at splices, sheeting with pressure sensitive adhesives shall be overlapped not less than 5 mm. Where screen printing with transparent colours is proposed, only butt jointing shall be used. The material shall cover the sign surface evenly and shall be free from twists, cracks and folds. Cut-outs to produce legends and borders shall be bonded with the sheeting in the manner specified by the manufacturer.

801.3.15 **Warranty and durability :** The Contractor shall obtain from the manufacture a ten year warranty for satisfactory field performance including stipulated retro-reflectance of the retro-reflective sheeting of micro-prismatic sheeting, a seven-year warranty for high intensity grade and a five year warranty for the sheeting of engineering grade and submit the same to the Engineer. In addition, a ten year, seven year and a five year warranty for satisfactory in-field performance of the finished sign with retro-reflective sheeting of micro prismatic, high intensity grade and engineering grade respectively, inclusive of the screen printed or cut out letters/legends and their bonding to the retro-reflective sheeting shall be obtained from the contractor/supplier and submitted to the Engineer. The Contractor/ supplier shall also furnish the LOT numbers and certification that the signs and materials supplied against the assigned work meets all the stipulated requirements and carry the stipulated warranty and that the contractor/supplier is the authorized converter of the particular sheeting.

All signs shall be dated during fabrication with indelible markings to indicate the start of warranty. The warranty shall also cover the replacement obligation by the sheeting manufacturer as well as contractor for replacement/repair/restoration of the retro-reflective efficiency.

A certificate in original shall be given by the sheeting manufacturer that its offered retro-reflective sheeting has been tested for various parameters such as co-efficient of retro-reflection, day/night time colour and luminance, shrinkage, flexibility, linear removal, adhesion, impact resistance, specular gloss and fungus resistance; the tests shall be carried out by a Government Laboratory in accordance with various ASTM procedures and the results must show that the sheeting have passed the requirements for all the above mentioned parameters. A copy of the test reports shall be attached with the certificate.

801.4 Installation

801.4.1 The traffic signs shall be mounted on support posts, which may be of GI pipes conforming to IS:1239, Rectangular Hollow Section conforming to IS :4923 or Square Hollow Section conforming to IS:3589. Sign posts, their foundations and sign mountings shall be so constructed as to hold these in a proper and permanent position against the normal storm wind loads or displacement by vandalism. Normally, signs with an area up to 0.9 sq.m shall be mounted on a single post, and for greater area two or more supports shall be provided. Post-end(s) shall be firmly fixed to the ground by means of properly

designed foundation. The work of foundation shall conform to relevant Specifications as specified.

801.4.2 All components of signs (including its back side) and supports, other than the reflective portion and G.I. posts shall be thoroughly de scaled, cleaned, primed and painted with two coats of epoxy/ fibre glass/ powder coated paint. Any part of support post below ground shall be painted with protective paint.

801.4.3 The signs shall be fixed to the posts by welding in the case of steel posts and by bolts and washers of suitable size. After the nuts have been tightened, the tails of the bolts shall be furred over with a hammer to prevent removal.

801.5 Measurements for Payment

The measurement of standard cautionary, mandatory and information signs shall be in numbers of different types of signs supplied and fixed, while for direction and place identification signs, these shall be measured by area in square metres.

801.6 Rate

The Contract unit rate shall be payment in full for the cost of making the road sign, including all materials, installing it at the site furnishing of necessary test certificates, warranty and incidentals to complete the work in accordance with these Specifications.

802 OVERHEAD SIGNS

802.1 General

802.1.1 Overhead signs may be used in lieu of, or as an adjunct to, kerb mounted signs where the situation so warrants for proper information and guidance of the road users. The following conditions may be considered while deciding about the provision of overhead signs:

- Traffic volume at or near capacity
- Complex interchange design
- Three or more lanes in each direction
- Restricted sight distance
- Closely spaced interchanges
- Multi-lane exits
- Large percentage of commercial vehicles
- High speed traffic

- Insufficient space for ground mounted signs
- Background of street lighting
- Distances of important places en route highways at suitable intervals.

802.1.2 From safety and aesthetic considerations, overhead signs shall be mounted on overhead bridge structures. Where these are required to be provided at some other locations, the support system providing pleasing aesthetics, should be properly designed based on sound engineering principles, to safely sustain the dead load, live load and wind load on the completed sign system. For this purpose, the overhead signs shall be designed to withstand a wind loading of 150 kg/m^2 normal to the face of the sign and 30 kg/m^2 transverse to the face of the sign. In addition to the dead load of the structure, walkway loading of 250 kg concentrated live load shall also be considered for the design of the overhead sign structure.

802.2 Height

Overhead signs shall provide a vertical clearance of not less than 5.5 m over the entire width of the pavement and shoulders except where a lesser vertical clearance is used for the design of other structures. The vertical clearance to overhead sign structures or supports need not be greater than 300 mm in excess of the minimum clearance of other structures.

802.3 Lateral Clearance

802.3.1 The minimum clearance outside the usable roadway shoulder for signs mounted at the road side or for overhead sign supports either to the right or left side of the roadway shall be 1.80 m. This minimum clearance of 1.80 m shall also apply outside of an unmountable kerb. Where practicable, a sign should not be less than 3 m from the edge of the nearest traffic lane. Large guide signs should be farther removed preferably 9 m or more from the nearest traffic lane, unless otherwise specified. Lesser clearances, but not generally less than 1.80 m, may be used on connecting roadways or ramps at inter-changes.

802.3.2 Where a median is 3.6 m or less in width, consideration should be given to spanning over both roadways without a central support. Where overhead sign supports cannot be placed at a safe distance away from the line of traffic or in an otherwise protected site, they should either be so designed as to minimize the impact forces or protect motorists adequately by a physical barrier or guard rail of suitable design.

802.4 Number of Signs at an Overhead Installation

In no case shall there be more than three signs displayed at any one location, including regulatory or warning signs, either on the overhead structure or on its support.

802.5 Materials for Overhead Sign and Support Structures

802.5.1 Aluminium alloy or galvanized steel to be used as truss design supports shall conform to relevant IS. These shall be of sections and type as per structural design requirements as shown on the plans.

802.5.2 After steel trusses have been fabricated and all required holes punched or drilled on both the horizontal truss units and the vertical and support units, they shall be galvanized in accordance with IS Specifications.

802.5.3 Where aluminium sheets are used for road signs, they shall be of smooth, hard and corrosion resistant aluminium alloy conforming to IS:736- Material Designation 24345 or 1900. The thickness of sheet shall be related to the size of the sign with minimum thickness of sheet as 1.5 mm.

802.5.4 High strength bolts shall conform to IS:1367 whereas precision bolts, nuts etc. shall conform to IS:1364.

803.5.5 Plates and support sections for sign posts shall conform to IS:226 and IS:2062.

802.5.6 The overhead signs shall be of micro prismatic retro reflective sheeting.

802.6 Size and Locations of Signs

802.6.1 The size of the signs, letters and their placement shall be as specified in the Contract drawings and Specifications.

802.6.2 In the absence of details or for any missing details in the Contract documents, the signs shall be provided as directed by the Engineer.

802.7 Installation

802.7.1 The supporting structure and signs shall be fabricated and erected as per details given in the plans and at locations directed by the Engineer.

802.7.2 Sign posts, their foundations and sign mountings shall be so constructed as to hold signs in a proper and permanent position to adequately resist swaying in the wind or displacement by vandalism.

802.7.3 The work of construction of foundation for sign supports including excavation and backfill, forms, steel reinforcement, concrete and its placement shall conform to the relevant Specifications given in these Specifications.

802.7.4 The structures shall be erected with the specified camber and in such a manner as to prevent excessive stresses, injury and defacement.

802.7.5 Brackets shall be provided for mounting signs of the type to be supported by the structure. For better visibility, they shall be adjustable to permit mounting the sign faces at any angle between a truly vertical position and three degree from vertical. This angle shall be obtained by rotating the front lower edge of the sign forward. All brackets shall be of a length equal to the heights of the signs being supported.

802.7.6 Before erecting support structures, the bottom of each base plate shall be protected with an approved material which will adequately prevent any harmful reaction between the plate and the concrete.

802.7.7 The end supports shall be plumbed by the use of leveling nuts and the space between the foundation and base plate shall be completely filled with an anti-shrink grout.

802.7.8 Anchor bolts for sign supports shall be set to proper locations and elevation with templates and carefully checked after construction of the sign foundation and before the concrete has set.

802.7.9 All nuts on aluminium trusses, except those used on the flanges shall be tightened only until they are snug. This includes the nuts on the anchor bolts. A thread lubricant shall be used with each aluminium nut.

802.7.10 All nuts on galvanized steel trusses, with the exception of high strength bolt connections, shall be tightened only to a snug condition.

802.7.11 Field welding shall not be permitted.

802.7.12 After installation of signs is complete, the sign shall be inspected by the Engineer. If specular reflection is apparent on any sign, its positioning shall be adjusted by the Contractor to eliminate or minimize this condition.

802.8 Measurements for Payment

802.8.1 Aluminium or steel overhead sign structure will be measured for payment by the specific unit (each) complete in place or for each component of the overhead sign structure as indicated in the Bill of Quantities and the detailed drawings(s).

802.8.2 Flat sheet aluminium signs with retro-reflective sheeting thereon shall be measured for payment by the square metre for each thickness, complete in place.

802.9.1 The structural steel part of the overhead sign shall be measured in tonnes while the sign board shall be measured in sq.m. Other items like excavation for foundation

and concrete in foundation to be measured and paid in cu.m separately. The Contract unit rate for overhead sign structure shall be payment in full compensation for furnishing all labour, materials, tools, equipment, excavation for foundation, concrete, reinforcement, painting of structural steel and sign back, fabrications and installation, furnishing of necessary test certificates, warranty and all other incidental costs necessary to complete the work to these Specifications.

802.9.2 The Contract unit rate for aluminium sheet signs shall include the cost of making the sign including all materials and fixing the same in position and all other incidental costs necessary to complete the work to these Specifications.

803 ROAD MARKINGS

803.1 General

The colour, width and layout of road markings shall be in accordance with the Code of Practice for Road Markings with paints, IRC:35 :1997, and as specified in the drawings or as directed by the Engineer.

803.2 Materials

Road markings shall be hot applied thermoplastic compound, reflectorised paint or cold applied reflective paint as specified in the item and the material shall meet the requirements as specified in these Specifications.

803.3 Ordinary Road Marking Paint

803.3.1 Ordinary paint used for road marking shall conform to Grade I as per IS:164.

803.3.2 The road marking shall preferably be laid with appropriate road marking machinery.

803.4 Hot Applied Thermoplastic Road Marking

803.4.1 General :

i) The work under this section consists of marking traffic stripes using a thermoplastic compound meeting the requirements specified herein.

ii) The thermoplastic compound shall be screeded/extruded on to the pavement surface in a molten state by suitable machine capable of controlled preparation and laying with surface application of glass beads at a specific rate. Upon cooling to ambient pavement temperature, it shall produce an adherent pavement marking of specified thickness and width and be capable of resisting deformation by traffic.

iii) The colour of the compound shall be white or yellow (IS colour No. 356) as specified in the drawings or as directed by the Engineer.

iv) Where the compound is to be applied to cement concrete pavement, a sealing primer as recommended by the manufacturer, shall be applied to the pavement in advance of placing of the stripes to ensure proper bonding of the compound. On new concrete surface any laitance and/or curing compound shall be removed before the markings are applied.

803.4.2 Thermoplastic material

803.4.2.1 General : The thermoplastic material shall be homogeneously composed of aggregate, pigment, resins and glass reflectorizing beads.

803.4.2.2 Requirements :

i) **Composition** : The pigment, beads, and aggregate shall be uniformly dispersed in the resin. The material shall be free from all skins, dirt and foreign objects and shall comply with requirements indicated in Table 800-8.

Table 800-8 Proportions of Constituents of Marking Material (Percentage by Weight)

Component	White	Yellow
Binder	18.0 min.	18.0 min.
Glass Beads	30-40	30-40
Titanium Dioxide	10.0 min.	—
Calcium Carbonate and Inert Fillers	42.0 max.	See Note below
Yellow Pigments	—	See Note below

Note: Amount of yellow pigment, calcium carbonate and inert fillers shall be at the option of the manufacturer, provided all other requirements of this Specification are met.

ii) **Properties** : The properties of thermoplastic material, when tested in accordance with ASTM D36/BS-3262-(Part I), shall be as below:

a) Luminance:

White : Daylight luminance at 45°-65 percent min. as per AASHTO M 249

Yellow : Daylight luminance at 45°-45 percent min. as per AASHTO M 249

b) Drying time : When applied at a temperature specified by the manufacturer and to the required thickness, the material shall set to bear traffic in not more than 15 minutes.

c) Skid resistance : not less than 45 as per BS:6044.

d) Cracking resistance at low temperature : The material shall show no cracks on application to concrete blocks.

e) Softening point : 102.5°C $\pm$ 9.5°C as per ASTM D 36.

f) Yellowness index (for white thermoplastic paint) : not more than 0.12 as per AASHTO M 249

iii) **Storage life** : The material shall meet the requirements of these Specifications for a period of one year. The thermoplastic material must also melt uniformly with no evidence of skins or unmelted particles for the one year storage period. Any material not meeting the above requirements shall be replaced by the manufacturer/ supplier/Contractor.

iv) **Reflectorisation** : Shall be achieved by incorporation of beads, the grading and other properties of the beads shall be as specified in Clause 803.4.3.

v) **Marking** : Each container of the thermoplastic material shall be clearly and indelibly marked with the following information:

1) The name, trade mark or other means of identification of manufacturer

2) Batch number

3) Date of manufacture

4) Colour (white or yellow)

5) Maximum application temperature and maximum safe heating temperature.

vi) **Sampling and testing** : The thermoplastic material shall be sampled and tested in accordance with the appropriate ASTM/BS method. The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturers of the thermoplastic material showing results of all tests specified herein and shall certify that the material meets all requirements of this Specification.

803.4.3 Reflectorizing glass beads

803.4.3.1 General : This Specification covers two types of glass beads to be used for the production of reflectorised pavement markings.

Type 1 beads are those which are a constituent of the basis thermoplastic compound vide Table 800-8 and Type 2 beads are those which are to be sprayed on the surface vide Clause 803.5.1.3.

803.4.3.2 The glass beads shall be transparent, colourless and free form milkiness, dark particles and excessive air inclusions.

These shall conform to the requirements spelt out in Clause 803.4.3.3.

803.4.3.3 Specific requirements

a) **Gradation :** The glass beads shall meet the gradation requirements for the two types as given in Table 800-9.

Table 800-9 Gradation Requirements for Glass Beads

Sieve size	Per cent retained	
	Type 1	Type 2
1.18 mm	0 to 3	
850 micron	5 to 20	0 to 5
600 –do-	—	5 to 20
425 –do-	65 to 95	—
300 -do-	—	30 to 75
180 –do-	0-10	10 to 30
Below 180 micron	—	0 to 15

b) **Roundness :** The glass beads shall have a minimum of 70 per cent true spheres.

c) **Refractive index :** The glass beads shall have a minimum refractive index of 1.50.

d) **Free flowing properties :** The glass beads shall be free of hard lumps and clusters and shall dispense readily under any conditions suitable for paint striping. They shall pass the free flow-test.

803.4.3.4 **Test methods:** The specific requirements shall be tested with the following methods:

i) Free-flow test : Spread 100 grams of beads evenly in a 100 mm diameter glass dish. Place the dish in a 250 mm inside diameter desiccator which is filled within 25 mm of the top of a desiccator plate with sulphuric acid water solution (specific gravity 1.10). Cover

the desiccator and let it stand for 4 hours at 20°C to 29°C. Remove sample from desiccator, transfer beads to a pan and inspect for lumps or clusters. Then pour beads into a clean, dry glass funnel having a 100 mm stem and 6 mm orifice. If necessary, initiate flow by lightly tapping the funnel. The glass spheres shall be free of lumps and clusters and shall flow freely through the funnel.

ii) The requirements of gradation, roundness and refractive index of glass beads and the amount of glass beads in the compound shall be tested as per BS:6088 and BS:3262 (Part I).

iii) The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturer of glass beads obtained from a reputed laboratory showing results of all tests specified herein and shall certify that the material meets all requirements of these Specifications. However, if so required, these tests may be carried out as directed by the Engineer.

803.4.4 Application properties of thermoplastic material

803.4.4.1 The thermoplastic material shall readily get screeded/extruded at temperatures specified by the manufacturers for respective method of application to produce a line of specified thickness which shall be continuous and uniform in shape having clear and sharp edges.

803.4.4.2. The material upon heating to application temperatures shall not exude fumes, which are toxic, obnoxious or injurious to persons or property.

803.4.5 Preparation

i) The material shall be melted in accordance with the manufacturer's instructions in a heater with a mechanical stirrer to give a smooth consistency to the thermoplastic material to avoid local overheating. The temperature of the mass shall be within the range specified by the manufacturer, and shall on no account be allowed to exceed the maximum temperature stated by the manufacturer. The molten material should be used as expeditiously as possible and for thermoplastic material which has natural binders or is otherwise sensitive to prolonged heating, the material shall not be maintained in a molten condition for more than 4 hours.

ii) After transfer to the laying equipment, the material shall be maintained within the temperature range specified by the manufacturer for achieving the desired consistency for laying.

803.4.6 Properties of finished road marking

a) The stripe shall not be slippery when wet.

b) The marking shall not lift from the pavement in freezing weather.

c) After application and proper drying, the stripe shall show no appreciable deformation or discoloration under traffic and under road temperatures upto 60^oC.

d) The marking shall not deteriorate by contact with sodium chloride, calcium chloride or oil dripping from traffic.

e) The stripe or marking shall maintain its original dimensions and position. Cold ductility of the material shall be such as to permit normal movement with the road surface without chopping or cracking.

f) The colour of yellow marking shall conform to IS Colour No. 356 as given in IS: 164.

803.5 Reflectorised Paint

Reflectorised paint, if used, shall conform to the Specification by the manufacturers and approved by the Engineer. Reflectorising glass beads for reflectorising paints where used shall conform to the requirements of Clause 803.4.3.

803.5.1 Application

803.5.1.1 Marking shall be done by machine. For locations where painting cannot be done by machine, approved manual methods shall be used with prior approval of the Engineer. The Contractor shall maintain control over traffic while painting operations are in progress so as to cause minimum inconvenience to traffic compatible with protecting the workmen.

803.5.1.2 The thermoplastic material shall be applied hot either by screeding or extrusion process. After transfer to the laying apparatus, the material shall be laid at a temperature within the range specified by the manufacturer for the particular method of laying being used. The paint shall be applied using a screed or extrusion machine.

803.5.1.3 The pavement temperature shall not be less than 10^oC during application. All surfaces to be marked shall be thoroughly cleaned of all dust, dirt, grease, oil and all other foreign matter before application of the paint.

The material, when formed into traffic stripes, must be readily renewable by placing an overlay of new material directly over an old line. Such new material shall so bond itself to the old line that no splitting or separation takes place.

Thermoplastic paint shall be applied in intermittent or continuous lines of uniform thickness of at least 2.5 mm unless specified otherwise. Where arrows or letters are to be provided, thermoplastic compound may be hand-sprayed. In addition to the beads included in the material, a further quantity of glass beads of Type 2, conforming to the above noted Specification shall be sprayed uniformly into a mono-layer on to the hot paint line in quick succession of the paint spraying operation. The glass beads shall be applied at the rate of 250 grams per square metre area.

803.5.1.4 The minimum thickness specified is exclusive of surface applied glass beads. The method of thickness measurement shall be in accordance with Appendices B and C of BS:3262 (Part 3).

803.5.1.5 The markings shall be done to accuracy within the tolerances given below:

i) Width of lines and other markings shall not deviate from the specified width by more than 5 percent.

ii) The position of lines, letters, figures, arrows and other markings shall not deviate from the position specified by more than 20 mm

iii) The alignment of any edge of a longitudinal line shall not deviate from the specified alignment by more than 10 mm in 15 m.

iv) The length of segment of broken longitudinal lines shall not deviate from the specified length by more than 150 mm.

In broken lines, the length of segment and the gap between segments shall be indicated on the drawings if these lengths are altered by the Engineer, the ratio of the lengths of the painted sections shall remain the same.

803.5.1.6 The finished lines shall be free from ruggedness on sides and ends and be parallel to the general alignment of the carriageway. The upper surface of the lines shall be level, uniform and free from streaks.

803.5.2 Measurements for Payment

803.5.2.1 The painted markings shall be measured in sq. metres of actual area marked (excluding the gaps, if any).

803.5.2.2 In respect of markings like directional arrows and lettering, etc., the measurement shall be by numbers.

803.5.3 Rate

The Contract unit rate for road markings shall be payment in full compensation for furnishing all labour, materials, tools, equipment, including all incidental costs necessary for carrying

out the work at the site conforming to these Specifications complete as per the approved drawing(s) or as directed by the Engineer and all other incidental costs necessary to complete the work to these Specifications.

803.6 Cold Applied Reflective Paint

803.6.1 General

The work shall consist of marking traffic stripes using a solvent based cold applied paint, which shall be applied on the asphalt/cement concrete road surface by brush or by Road Marker (Spray equipment capable of spraying the paint on the road) Glass beads shall be subsequently spread pneumatically on to the paint when it is still wet so that the beads will be firmly held by the paint after drying. Colour of the paint shall be white or yellow (IS Colour No. 356) as specified in the drawings or as directed by the Engineer.

803.6.2 Material

803.6.2.1 The cold applied paint material shall be homogeneously composed or binder, pigment, extenders and other additives as required for the formulation.

803.6.2.2 Composition : The pigments and extenders shall be uniformly dispersed in the binder medium dissolved in organic solvents. The material shall be free from skin, dirt and foreign objects and shall comply with requirements indicated in Table 800-10

Table 800-10 Proportions of Constituents or Paint (Percentage by weight)

Component	White	Yellow
Binder	25.0 min.	18.0 min.
Titanium Dioxide	20.0 min.	—
Calcium Carbonate and Inert Fillers	16.0 min.	29.0 min.
Yellow Pigments	——	14.0 min.

803.6.2.3 Properties *:* Non-Volatile Matter content by weight shall be a minimum of 65 pecent as determined in accordance with test method ASTM D1644. The liquid paint shall have a density of 1.3 minimum as determined in accordance with test method ASTM D1475.

803.6.2.4 Appearance : Drying Time of the paint as determined by the test method ASTM D711 shall be a maximum of 20 minutes at a wet film thickness of 350 micron. The paint shall set to bear traffic after 40 minutes when the ambient temperature is higher than 24ºC. The paint shall not be applied when the surface temperature of the road is higher than 40ºC.

803.6.2.5 Properties of the dried paint film : When tested using a sand abrasion tester as described in ASTM D968, the quantity of sand required for removal of a 75 micron thick unbeaded dry film shall be greater than 65 litres.

803.6.2.6 Elongation : The unbeaded dry film shall pass the test in accordance with ASTM D 1737 and ASTM D 2205.

803.6.2.7 Water Resistance : The unbeaded dry film shall pass the test in accordance with ASTM D1647 and ASTM D2205.

803.6.2.8 Skid resistance : Skid resistance for the beaded dry film shall be not less than 45 as per BS 6044.

803.6.2.9 Storage life : The material shall meet the specifications for a period of one year. During this period, the paint material when stored in an airtight container shall not form skin. The material shall also not form a cake at the bottom of the container.

803.6.2.10 Minimum thickness of the Unbeaded Cold Applied Paint Coat : The minimum thickness of the wet unbeaded coat of paint shall not be less than 400 micron, and the minimum thickness of the dry unbeaded coat of paint shall not be less than 200 microns.

803.6.2.11 Retro-reflective Properties : The co-efficient of retro-reflection as per British Standards BS EN 1436: 1998 shall be as under:

For white paint (Beaded)	– 300 mcd/m^2/lux on application
	– 100 mcd/m^2/lux after defect liability period of one year
For yellow paint (Beaded)	– 200 mcd/m^2/lux on application
	– 100 mcd/m^2/lux after defect liability period of one year

The luminous Co-efficient as per British Standards BS EN 1436:1998 shall be as under:

For white paint (Unbeaded)	– 100 mcd/m^2/lux on application
For yellow paint (Unbeaded)	– 80 mcd/m^2/lux on application

803.6.3 Marking

Each container of the cold-paint shall be clearly and indelibly marked with the following information:

i) The name, trade/patent mark

ii) Batch No.

iii) Month of Manufacture

iv) Colour (Whitel or Yellow)

803.6.4 Sampling and testing

The cold applied reflective road marking paint shall be sampled and tested in accordance with appropriate ASTM/BS test methods.

The contractor shall furnish to the Engineer a copy of certified test methods from the manufacturer of cold applied reflective road marking paint showing the results of:

a) No pick up time as per ASTM D 711.

b) Resistance to wear as per ASTM D4060 or as per ASTM D968 from approved laboratories.

c) Material safety data sheet shall be obtained from the manufacturer and kept with the paint materials.

803.6.5 Reflectorising glass beads

803.6.5.1 General : Reflection is achieved by pneumatically spreading glass beads on to the paint when it is still wet. The beads will be firmly held by the paint after drying.

803.6.5.2 The glass beads shall be transparent, colourless and free from milkiness, dark particles and excessive air inclusions. These shall conform to the requirements spelt out in Clause 803.6.5.3.

803.6.5.3 Specific requirements

i) **Gradation** : The glass beads shall meet the gradation requirements as per No. 4 of BS:6088 as given in Table 800-11.

Table 800-11 Gradation Requirements for Glass Beads

Sieve Size	Percentage Retained
250 micron	0-10
150 micron	80-100
Below 150 micron	0-20

ii) **Roundness** : The glass beads shall have a minimum of 70 per cent true Spheres.

iii) **Refractive Index** : The glass beads shall have a minimum refractive Index of 1.50.

iv) **Free flowing properties** : The glass beads shall be free of hard lumps, clusters and shall dispense readily under any conditions suitable for paint striping. They shall pass the free flow-test as given in Clause 803.6.5.4.

803.6.5.4 **Test Methods** : The specific requirements shall be tested with the following methods:

i) Free-flow test: Spread 100 grams of beads evenly in a 100 mm diameter glass dish. Place the dish in a 250 mm inside diameter desiccator which is filled within 25 mm of the top of a desiccator plate with sulphuric acid water solution (specific gravity 1.10). Cover the desiccators and let it stand for 4 hours at 20ºC to 29ºC. Remove sample from desiccator, transfer beads to a pan and inspect for lumps or clusters. Then pour beads into a clean, dry glass funnel having a 100 mm stern and 6 mm orifice. If necessary, initiate flow by lightly tapping the funnel. The glass spheres shall be free of lumps and clusters and shall flow freely through the funnel.

ii) The requirements of gradation, roundness and refractive index of glass beads and the amount of glass beads in the compound shall be tested as per BS:6088 and BS:3262(Part-1)

iii) The Contractor shall furnish to the Engineer a copy of certified test reports from the manufacturer of glass beads obtained from a reputed laboratory showing results of all tests specified herein and shall certify that the material meets all requirements of these Specifications. However, if so required, these tests may be carried out as directed by the Engineer.

803.6.5.5 Application

803.6.5.5.1 Marking shall be done by machine. For locations where painting can not be done by machine, approved manual methods shall be used with prior approval of the Engineer. The Contractor shall maintain control over traffic while painting operations are in progress so as to cause minimum inconvenience to traffic compatible with protecting the workmen.

803.6.5.5.2 The cold applied paint shall be applied on the asphalt/cement concrete road surface by brush or by Road Marker/Spray equipment capable of spraying the paint on the road surface. Glass beads @ 300 gms per sq.m shall be subsequently spread pneumatically on to the paint when it is still wet so that the beads will be firmly held by the paint after drying.

803.6.5.5.3 The pavement temperature shall not be more than 40ºC during application. All surfaces to be marked shall be thoroughly cleaned of all dust, dirt, grease oils and all other foreign matter before application of paint.

803.6.5.5.4 The material, when formed into traffic stripes, must be readily renewable by placing an overlay of a new material directly over an old line. Such new material shall so bond itself to the old line that no splitting or separation takes place.

803.6.5.5.5 Cold applied paint shall be applied in intermittent or continues lines of uniform thickness of at least 200 micron of unbeaded dry film thickness unless specified otherwise. When arrows or letters are to be provided, cold applied paint may be applied manually. In addition to the beads recommended for, a further quantity of 300 gms of glass beads per sqm. conforming to the specification shall be sprayed uniformly in to a mono-layer on to the cold paint line in quick succession of the cold paint spraying operation.

803.6.5.5.6 The minimum. thickness specified above in Clause 803.6.5.5.5 is exclusive of surface applied glass beads.

803.6.5.5.7 The finished line shall be free from ruggedness on sides and ends and be parallel to general alignment of the carriage way.

The upper surface of the lines shall be of uniform level and free from streaks.

803.6.5.6 **Preparation** : The cold applied reflective road marking paint shall be stirred well to form homogeneously with the thinner recommended/supplied by the manufacturer and put into the machine with the consistency level recommended by the machine manufacturer by using proper viscometers. The thinner shall not be added more than that recommended by the manufacturer to avoid bleeding.

803.6.5.7 **Properties of finished road marking :**

a) The stripe shall not be slippery when wet.

b) The marking shall not lift from the pavement in freezing weather.

c) After application and proper drying, the stripe shall show no appreciable deformation or discoloration under traffic and under road temperatures up to 60ºC.

d) The marking shall not deteriorate by contact with sodium chloride, calcium chloride or oil drippings from traffic.

e) The stripe or marking shall maintain its original dimensions and position. Cold ductility of the material shall be such as to permit normal movement with the road surface without chopping or cracking.

f) The colour of yellow marking shall conform to IS colour No. 356 as given in IS:164.

803.6.6 Measurement for payments : The painted markings shall be measured in Sq.m of actual area marked (excluding the gaps, if any).

803.7 Audible and Vibratory Pavement Markings

803.7.1 Description

The work shall involve application of audible and vibratory pavement markings in accordance with the drawings or the direction of the Engineer.

803.7.2 Materials

Thermoplastic : Thermoplastic material shall meet the requirements of Clause 803.4.2 of these Specifications.

Glass Spheres : Use glass spheres meeting the requirements of Clause 803.4.3. The Engineer will take random samples of glass spheres in accordance with ASTM D1214 and the Department's Sampling, Testing and Reporting Guide schedule.

803.7.3 Equipment

The equipment capable of providing continuous, uniform heating of the striping material to temperatures exceeding 200ºC, mixing and agitating the material in the reservoir shall be used to provide a homogenous mixture without segregation. Equipment will maintain the striping material in a plastic state, in all mixing and conveying parts, including the line dispensing device until applied. Equipment shall be capable of producing a consistent pattern of transverse bars positioned at regular and predetermined intervals. It shall meet the following requirements:

a) capable of traveling at a uniform rate of speed, both uphill and downhill, to produce a uniform application of striping material and capable of following straight lines and making normal curves in a true arc.

b) capable of applying glass spheres to the surface of the completed stripe by automatic sphere dispensers attached to the striping machine such that the glass spheres are dispensed closely behind the installed line. The glass sphere dispensers should be equipped with an automatic cut-off control that is synchronized with the cut-off of the thermoplastic material and applies the glass spheres uniformly on the entire traffic stripe surface with 50 percent to 60 percent embedment equipped with a special kettle for uniformly heating and melting the striping material.

c) equipped with special kettle for uniformly heating and melting the stripping material. The kettle must be equipped with an automatic temperature control device and material thermometer for positive temperature control and to prevent overheating or scorching of the thermoplastic material.

d) meets the requirements of the fire safety standards.

803.7.4 Application

803.7.4.1 General : Before applying traffic stripes and markings, any material that would adversely affect the bond of the traffic stripes shall be removed by a method approved by the Engineer.

Before applying traffic stripes to any portland cement surface, a primer, sealer or surface preparation adhesive of the type recommended by the manufacturer shall be applied. Longitudinal lines should be offset by at least 50 mm from construction joints of portland cement concrete pavement.

Traffic stripes or markings shall be applied only to dry surface, and when the ambient air and surface temperature is at least 10ºC and rising for asphalt surfaces and 16ºC and rising for concrete surface.

Striping shall be applied to the same tolerances in dimensions and in alignment. When applying traffic stripes and marking over existing markings, ensure that not more than 50 mm on either end and not more than 25 mm on either side of the existing line is visible.

803.7.4.2 Thickness: Base lines shall be applied having a thickness of 2 mm to 2.2 mm exclusive of the transverse audible bars, when measured above the pavement surface at the edge of the base line.

As an alternative to the flat base line, a profiled baseline meeting the following dimensions may be applied. The profiled baseline shall have a minimum height of 4 mm, when measured above the pavement surface at the edge of the inverted rib profile. The thickness in the bottom of the profile marking shall be 0.9 mm to 1.3 mm. The individual profiles shall be located transversely across the full width of the traffic stripe at approximately 25 mm. On center, with a bottom width between 2.5 mm and 8 mm.

803.7.5 Dimensions of Transverse Audible Bars: The raised transverse bars shall be applied with a profile such that the leading and trailing edge are sloped at a sufficient angle to create an audible and vibratory warning,

Transverse bars on shoulder and centerline markings shall have a height of 11 mm to 14 mm, including the base line. The height shall be measured above the pavement surface at

the edge of the marking, after application of drop-on glass spheres. The bars shall have an approximate length of 65 mm. The bars may have a drainage channel on each bar, the width of each drainage channel will not exceed 6.5 mm at the bottom of the channel. The longitudinal distance between bars shall be 750 mm.

803.7.6 Retroreflectivity : White and yellow audible and vibratory markings shall attain an initial retro reflectance of not less than 300 mcd/1x.m^2 and not less than 250 mcd/1x m^2, respectively. .

803.7.7 Glass spheres : Apply glass spheres to all markings. The manufacturer shall determine if a single or double application of glass spheres is used and the recommended drop rates for each application.

803.7.8 Contractor's responsibility

The Engineer shall be notified by the Contractor, prior to the placement of audible and vibratory markings. The contractor shall furnish the Engineer with the manufacturer's name and LOT numbers of the thermoplastic materials and glass spheres to be used. He will ensure that the LOT numbers appear on the thermoplastic materials and glass spheres packages. The Contractor shall furnish a copy of certified test reports to the Engineer, showing results of tests specified in these Specifications or as per appropriate ASTM/BS method. The Engineer would have the right to test the markings within 3 days of receipt of the Contractor's certification. If the retro reflectivity values measure less than the values shown above, it shall be removed and the stripping reapplied.

803.7.9 Protection of newly applied audible and vibratory markings

Traffic shall not be allowed onto or vehicles permitted to cross newly applied pavement markings until they are sufficiently dry. Any portion of the pavement markings damaged by passing traffic or from any other cause shall be removed and replaced.

803.7.10 Observation period

Pavement markings shall be subject to a 180 day observation period under normal traffic. The observation period will begin with the satisfactory completion and acceptance of the pavement marking work. The pavement markings shall show no signs of failure during the observation period. The Contractor shall replace, at his own cost no expense to the Department, any pavement markings that do not perform satisfactorily under traffic during the 180 day observation period, shall be replaced by the Contractor at his own cost.

803.7.11 Measurement for payment

Audible and vibratory pavement markings shall be measured in linear meter. Payments will be full compensation for all work specified in this Section, including, all cleaning and

preparing of surfaces, furnishing of all materials, application, curing and protection of all items, protection of traffic, furnishing of all tools, machines and equipment, ad all incidentals necessary to complete the work. Final payment will be withheld until all deficiencies are corrected.

804 REFLECTIVE PAVEMENT MARKERS (ROAD STUDS)

804.1 General

The work cover the providing and fixing of reflective pavement marker (RPM) or road stud, a device which is bonded to or anchored within the road surface, for lane marking and delineation for night-time visibility. It reflects incident light in directions close to the direction from which it came.

804.2 Material

804.2.1 Plastic body of RPM/road stud shall be moulded from ASA (Acrylic Styrene Acrylonitrite) or HIPS (Hi-impact Polystyrene) or Acrylonitrile Butadiene Styrene (ABS) or any other suitable material approved by the Engineer. The markers shall support a load of 13,635 kg tested in accordance with ASTM D4280.

804.2.2 Reflective panels shall consist of number of lenses containing single or dual prismatic cubes capable of providing total internal reflection of the light entering the lens face. Lenses shall be moulded of methyl methecrylate conforming to ASTM D 788 or equivalent.

804.3 Design

The slope or retro-reflecting surface shall preferably be 35 ± 5° to base and. the area of each retro-reflecting surface shall not be less than 13.0 sq.cm.

804.4 Optical Performance

804.4.1 Unidirectional and bi-directional studs

Each reflector or combination of reflectors on each face of the stud shall have a Coefficient of Luminous Intensity (C.I.L). not less than that given in Table 800-12 or Table 800-13 as appropriate.

804.4.2 Omni-directional studs

Each Omni-directional stud shall have a minimum (C.I.L). of not less than 2 mcd/lx.

Table 800-12 Minimum C.I.L. Values for Category 'A' studs

Entrance angle	Observation angle	C.I.L. in mcd/lx		
		White	Amber	Red
0° U 5° L &R	0.3°	220	110	44
0° U 10° L&R	0.5°	120	60	24

Table 800-13 Minimum C.I.L. Values for Category 'B' studs

Entrance angle	Observation angle	C.I.L. in mcd/lx		
		White	Amber	Red
0° U 6° L &R	0.3°	20	10	4
0° U 10° L&R	0.5°	15	7.5	3

Note : 1) The entrance angle of 0° U corresponds to the normal aspect of the reflectors when the reflecting road stud is installed in horizontal road surface.

2) The stud incorporating one or more corner cube reflectors shall be included in category 'A'. The stud incorporating one or more bi-convex reflectors shall be included in category 'B'.

804.5 Tests

804.5.1 Co-efficient of luminance intensity can be measured by procedure described in ASTM E 809 "Practice for Measuring Photometric Characteristics" or as recommended in BS:873-Part 4: 1973.

804.5.2 Under test conditions, a stud shall not be considered to fail the photometric requirements if the measured C.I.L. at any one position of measurement is less than the values specified in Table 800-12 or Table 800-13 provided that

i) the value is not less than 80 percent of the specified minimum, and

ii) the average of the left and right measurements for the specific angle is greater than the specified minimum.

804.6 Solar Powered Road Markers (Solar Studs)

The solar studs shall be made of Aluminium alloy and poly carbonate material which shall be absolutely weather resistance and strong enough to support a load of 13,635 kg tested in accordance with ASTM D4280. Its colour may be white, red, yellow, green or blue or combination as directed by the Engineer. Its water resistance shall meet the requirements of IP 65 in accordance with IS:12063:1987 Category 2 for protection against water ingress.

The dimensions of solar studs shall not be less than 100 mm x 100 mm x 10 mm. It shall have super bright LEDs so as to provide long visibility from a distance of more than 800 m. Its flashing rate shall not be less than 1 Hz. Its should be able to give the prescribed performance in the temperature range of -40ºC to +55ºC. Its life shall be not less than 3 years.

804.7 Fixing of Reflective Markers

804.7.1 Requirements

The enveloping profile of the head of the stud shall be smooth and the studs shall not present any sharp edges to traffic. The reflecting portions of the studs shall be free from crevices or ledges where dirt might accumulate. Marker height shall not be less than 10mm and shall not exceed 20 mm. and its width shall not exceed 130 mm. The base of the marker shall be flat within 1.3 mm. If the bottom of the marker is configured, the outermost faces of the configurations shall not deviate more than 1.3 mm from a flat surface. All road studs shall be legibly marked with the name, trade mark or other means of identification of the manufacturer.

804.7.2 Placement

The reflective marker shall be fixed to the road surface using the adhesives and the procedure recommended by the manufacturer. No nails shall be used to affix the marker so that they do not pose safety hazard on the roads. Regardless of the type of adhesive used, the markers shall not be fixed if the pavement is not surface dry and on new asphalt concrete surfacing until the surfacing has been opened to traffic for a period of not less than 14 hours. The portions of the highway surface, to which the marker is to be bonded by the adhesive, shall be free of dirt, curing compound, grease, oil, moisture, loose or unsound layers, paint and any other material which would adversely affect the bond of the adhesive. The adhesive shall be placed uniformly on the cleaned pavement surface or on the bottom of the of the marker in a quantity sufficient to result in complete coverage of the area of contract of the marker with no voids present and with a slight excess after the marker has been lightly pressed in place. For epoxy installations, excess adhesive around the edge of the marker, excess adhesive on the pavement and adhesive on the exposed surfaces of the markers shall be immediately removed.

804.7.3 Warranty and durability

The Contractor shall submit a two year warranty for satisfactory field performance including stipulated retro-reflectance of the reflecting panel, to the Engineer. In addition, a two year warranty for satisfactory infield performance of the finished road marker shall also be given by the Contractor who carries out the work of fixing of reflective road markers. In case the markers are displaced, damaged, get worn out or lose their reflectivity compared to

stipulated standards, the Contractor would be required to replace all such markers within 15 days of the intimation from the Engineer, at his own cost.

804.8 Measurement for Payment

The measurement of reflective road markers shall be in numbers of different types of markers supplied and fixed.

804.9 Rate

The contract unit rate for reflective road markers shall be payment in full compensation for furnishing all labour, material, tools, equipment including incidental costs necessary for carrying out the work at site conforming to the specification complete as per approved drawings or as directed by the Engineer.

805 DISTANCE MEASUREMENT DEVICES

805.1 General

The work shall cover the supply, painting, lettering and fixing of distance measurement devices along the highway to assist the drivers/users in estimating the distance travelled or remains to be travelled to reach destination, to identify incident location and to provide assistance in maintenance and operations. These devices shall show Hectometre , Kilometre and 5th Kilometres as the case may be.

805.2 The devices may be in accordance with those prescribed in IRC:26 "Type Designs for 200 Metre Stones" and IRC:8 "Type Designs for Highway Kilometre Stones". They may also be provided in the form of sign systems on highways and roads.

805.3 The material may be made of local stones, concrete or any other material available locally and approved by the Engineer for the devices in accordance with the IRC:26 and IRC:8. For the device(s) provided as the sign system, the material would be same as that for a traffic sign with retro reflective sheeting; rectangular in shape (longer side vertical), with colour scheme as that for Advance Direction/Destination signs. The signs shall contain 250 mm white numerals on a 300 mm wide blue or green background (as the case may be) with white border. They shall be 600, 900 or 1200 mm in height for one, two or three digits respectively and shall contain the abbreviation km in 100 mm white letters so that they are clearly visible to approaching vehicle driver from a distance of at least 100 m. They shall be mounted at a minimum height and lateral placement as that for delineators. These devices shall be bedded into the ground with adequate foundations as indicated in the drawings or in the relevant IRC Specifications or as directed by the Engineer. The orientation and location of the devices shall be as indicated in the drawings or in the relevant IRC Specifications or as directed by the Engineer.

805.4 Measurements for Payment

The measurement will be in numbers of 200 metre, kilometer and 5th kilometer distance measurement devices fixed at site, complete job as per these Specifications or as directed by the Engineer.

805.5 Rate

The Contract unit rate for hectometer/kilometer/5th kilometer distance measurement devices shall be payment in full compensation for furnishing all labor, materials, tools, equipment and making, painting and lettering and fixing at site and all other incidental costs necessary to complete the work to these Specifications.

806 ROAD DELINEATORS

806.1 General

The work covers supplying and fixing roadway indicators, hazard markers and object markers. Roadway indicators shall be properly installed to indicate the horizontal alignment and vertical profile of the roadway so as to outline the vehicle path for safe driving. Hazard markers shall be installed immediately ahead of obstruction of vehicular path such as just before a narrow bridge. Object markers shall be erected where obstruction within the roadway starts such as chennelising island in approaches to intersections.

806.2 The design, materials to be used and the location of the road delineators (roadway indicators, hazard markers and object markers) shall conform to Recommended Practice for Road Delineators, IRC:79, and to relevant drawings or as otherwise directed by the Engineer. The steel drums such as empty bitumen drums shall not be used as they could pose safety hazards,

The delineators shall be retro reflectorised as shown on the drawings or as directed by the Engineer. The reflectors on the delineators shall be of retro reflective sheeting with encapsulated lens and with the visibility of 300 m under clear weather conditions, when illuminated by the upper beam of the car headlights.

806.3 **Installation :** The delineators shall be so installed that their posts do not change their orientation and the reflectorised faces are always perpendicular to the direction of travel.

806.4 Measurement for Payments

The measurement shall be made in number of delineators supplied and fixed at site.

806.5 Rates

The Contract unit rates of delineators shall be payment in full compensation for furnishing all labour, materials, tools, equipment including incidentals costs necessary to complete the work to these Specifications.

807 BOUNDARY STONES

807.1 General

The work comprises of supplying and fixing boundary stones as per designs and Specifications given in IRC:25 “Type Designs for Boundary Stones” and at locations indicated in the drawings or as directed by the Engineer. The material to be used shall conform to IRC:25.

807.2 Measurements for Payment

The measurement shall be made in numbers of boundary stones supplied and fixed at site.

807.3 Rate

The Contract unit rate for boundary stones shall be payment in full compensation for furnishing all labour, materials, tools, equipment for preparing, supplying and fixing and all other incidental costs necessary to complete the work to these Specifications.

808 FENCING

808.1 General

The work comprises supply and installation of chain link fencing with its fixing on GI pipe posts and providing necessary stays and entry gates as shown in the drawing(s) and/or as directed by the Engineer.

808.2 The GI posts shall conform to IS:1239. The GI pipe posts shall be embedded in concrete to a sufficient depth below ground as indicated in the drawings. The steel shall be fabricated and painted to conform to Section 1900 of these Specifications.

808.3 The chain link fencing shall conform to ASTM F 1553–06. They shall be firmly secured to the posts such that the whole fencing remains intact.

808.4 Entry gate(s) shall be made of GI pipes or other metal as per the design shown in the drawing(S).

808.5 Measurements for Payments

The measurement shall be in running metre of fencing including the entry gates.

808.6. Rate

The Contract unit rate for fencing shall be payment in full compensation for furnishing all labour, materials, tools, equipment for fabrication and fixing at site and all other incidental costs necessary to complete the work to these Specifications.

809 TUBULAR STEEL RAILING

809.1 General

The work shall consist of supplying, fixing and erecting tubular steel railings as shown on the drawings and/or as directed by the Engineer.

809.2 The railing shall be of tubular steel in conformance to IS:1239. The fabrication and painting except for the final coat shall be completed before dispatch to the site. Prior to the painting, all surfaces shall be grit blasted to the satisfaction of the Engineer and pickled. The priming coat of paint shall be applied as soon as the steel has dried.

809.3 The posts shall be vertical and of the type as shown in the drawing with a tolerance not exceeding 6mm in a length of 3 m. The railing shall be erected true to line and grade.

809.4 Measurements for Payment

The railing shall be measured in linear metre from end to end along the face of the railing, including end and intermediate posts, with no deduction for gaps as shown on the drawings.

809.5 Rate

The Contract unit rate for Tubular Steel Railing shall be payment in full compensation for furnishing all labour, materials, tools, equipment and plant required for fabrication, connection, oiling, painting, temporary erection, inspection, test and final erection at site and all other incidental costs necessary to complete the work to these Specifications.

810 CRASH BARRIERS

810.1 General

810.1.1 The work shall consist of construction, provision and installation of crash barriers as shown in the drawing or as directed by the Engineer. The crash barrier is provided to absorb the impact energy and reduce the severity of accidents involving vehicles leaving the traveled way. It should be installed where the severity of accidents due to

striking the barrier, which is shielding the hazard, is lower than what it will be without the barrier.

810.1.2 The crash barriers can be classified as flexible, semi-rigid, or rigid. The flexible system is the most yielding type, which may be composed of wire rope fencing. Semi-rigid barriers offer requisite resistance to control the deflection of longitudinal member to an acceptable limit; metal beam crash barriers give this system. Rigid system does not deflect on impact but causes the maximum severity of impact, concrete crash barrier is the rigid system.

810.1.3 They are generally longitudinal roadside crash barriers and median barriers. Some of the commonly encountered roadside obstacles are bridge piers, abutments and railing ends, roadside rock mass, culverts, pipes and headwalls, cut slopes, retaining walls, lighting supports, traffic sign and signal supports, trees, and utility poles. Median barriers are provided to check head-on-collisions, especially on highways with narrow medians, caused by out-of-control vehicles jumping across the medians.

810.1.4 Raised curbs or drains should not be provided between the traveled way and the barriers. These destabilize the vehicle balance and disturb its equilibrium before it strikes the barrier, thus defeating the essential purpose of safety and redirection of the impacting vehicle.

810.2 Placement

810.2.1 Placement recommendations determine the exact layout of the barrier and should be made by the design engineer keeping in view the lateral offset of the barrier and flare rate. The final layout shall be a site specific combination of these factors. The barriers should be as far away from the traffic as possible and should preferably have uniform clearance between the traffic and the hazard.

810.2.2 As far as possible the safety barrier should be placed beyond 2.5 m of the traveled way. For long and continuous stretches, this offset is not critical. The distance between the barrier and the hazard should not be less than the deflection of the barrier by an impact of a full sized vehicle. In case of embankments, a minimum distance of 60 cm should be maintained between the barrier and the start of embankment slope or a hazard to prevent the wheels from dropping over the edge.

810.2.3 Flatter flare rates may be used particularly where extensive grading would be required to ensure a flat approach from the traveled way subject to the availability of right of way.

810.2.4 At locations, where the two adjacent carriage ways are at the same level, the barrier shall be placed in the center of the median, duly taking into consideration, the

drainage requirements. The placement of median barriers in cases where the two carriageways are at different levels is a function of the slopes between the two medians. In case the median barriers need to be flared e.g. for the protection of supports to overhead signs, the flare rates mentioned in Clause 810.5.6.2. above shall be followed.

810.2.5 Crash barriers should be provided with reflectors to enhance their visibility in the night time.

810.3 Warrants

810.3.1 The crash barriers shall be provided at following locations.

i) Where the height of embankment is 3m or more,

ii) Where the embankment is retained by retaining structure,

iii) Where the median is depressed, flushed or having the width of less than 4.5 m. The barriers shall be for both directions of travel,

iv) On valley side of highway in mountainous and steep terrain,

v) Between the main carriageway and footpath on bridges,

vi) At hazardous locations, as per the direction of the Engineer.

vi) On the highways with ADT more than 20,000 PCUs and with medians width less than 9m, median barriers are required. the probability of a vehicle crossing across the median is relatively low and median barriers in such cases are optional.

vii) Median barriers to shield fixed objects in narrow median. If necessary, median barriers should be flared to encompass a fixed object, which may be a lamp post, foundation of overhead signs, bridge pier etc.

viii) Any hazardous location as directed by the Engineer.

810.3.2 Medians with width between 9 and 15 m do not warrant a barrier unless there is an adverse history of median crossovers. Median barriers may be impractical where a road has a large number of closely spaced median openings since the barrier needs to be terminated with an end treatment at these points. An evaluation of the number of median openings, accident history, alignment, sight distance, design speed, traffic volume and median width need to be made prior to taking a decision to install a median barrier.

810.4 Concrete Crash Barrier

810.4.1 Materials

810.4.1.1 All materials shall conform to Section 1000—Materials for Structures as applicable, and relevant Clauses in Section 1600 shall govern the steel reinforcement.

The concrete barriers shall be constructed either by the "cast-in-place with fixed forms" method or the "extrusion or slip form" method or a combination thereof at the Contractor's option with the approval of the Engineer. Where "extrusion or slip form" method is adopted full details of the method and literature shall be furnished.

810.4.1.2 Concrete barriers shall be constructed with M 20 grade concrete or as indicated in the drawing and with thermo mechanically treated (TMT) deformed bars of grade S415 conforming to IS:1786.

810.4.1.3 An expansion joint with pre-moulded asphalt filler board shall be provided at the junctions of crash barrier on structure and crash barrier on the fill. The crash barrier on the fill shall be constructed in pieces of length not exceeding 20 m, with pre-moulded asphalt filler board joints.

810.4.2 Construction operations

810.4.2.1 The location of crash barrier shall be strictly adhered to as shown on the drawing and/or as directed by the Engineer. Concrete crash barriers shall present a smooth, uniform appearance in their final position, conforming to the horizontal and vertical lines shown on the plans or as ordered by the Engineer and shall be free of lumps, sags or other irregularities. The top and exposed faces of the barriers shall conform to the specified tolerances, as defined in Clause 810.4.2.4, when tested with 3 m straight edge, laid on the surface.

810.4.2.2 Based on evaluation of vehicle direction, sight distance, structural stability and the psychological effect of barrier height on driver reaction, the most desirable height of the median barrier is 80 cm. 'New Jersey' type is the most common shape of concrete crash barrier. Variations up to 50 mm in height of barrier can be made in the total height of the barrier to meet the site requirements. It is however important to maintain the height of lower slope between 20 cm and 35 cm so as to reduce the chances of overturning of the vehicles.

810.4.2.3 The concrete barrier may be precast in lengths upto 6 m depending upon the feasibility of transport and lifting arrangements. The minimum thickness of foundation may be 25 mm thick cement concrete or hot mix asphalt placed at the base of barrier to provide lateral restraint. Where more than 75 mm thick overlay on the road pavement is anticipated, the foundation step may be increased to 125 mm. However, longitudinal roadside concrete barrier should have elaborate footing design which is structurally safe unless sufficient earth support is available.

Backfilling to the concrete barriers shall be compacted in layers to the compaction of the surrounding earthwork.

810.4.2.4 Tolerance The overall horizontal alignment of rails shall not depart from the road alignment by more than ± 30 mm, nor deviate in any two successive lengths from straight by more than 6mm and the faces shall not vary more than 12 mm from the edge of a 3 m straight edge. Barriers shall be at the specified height as shown in the plans above the edge of the nearest adjacent carriageway or shoulder, within a tolerance of ± 30 mm.

810.4.3 End Treatment : The road side concrete barrier shall be provided with an end treatment by tapering the height of terminating end within a length of 8 m to 9 m. Median crash barrier shall be terminated sufficiently away from the median opening. It shall be provided with an end treatment, which shall be obtained by tapering the height of terminating end of the median barrier within a length of 8 m to 9 m.

810.4.4 Measurements for payment

All barriers will be measured by linear metres of completed and accepted length in place, corresponding end to end along the face of concrete barriers including approach and departure ends.

810.4.5 Rate

The Contract unit rate shall include full compensation for furnishing all labour, materials, tools, equipment and incidental costs necessary for doing all the work involved in constructing the concrete barrier complete in place in all respects as per these Specifications.

810.5 Metal Beam Crash Barrier

810.5.1 General

810.5.1.1 This work shall consist of furnishing and erection of metal beam crash barrier of dimensions and at locations as shown on the drawing(s) or as directed by the Engineer.

810.5.1.2 Metal beam crash barrier shall generally be located on approaches to bridge structures, at locations where the embankment height is more than 3 m and at horizontal curves.

810.5.2 Materials

810.5.2.1 Metal beam rail shall be corrugated sheet steel beams of the class, type, section and thickness indicated on the plans. Railing posts shall be made of steel of the section, weight and length as shown on the plans. All complete steel rail elements, terminal sections, posts, bolts, nuts, hardware and other steel fittings shall be galvanized. All elements of the railing shall be free from abrasions, rough or sharp edges and shall not be kinked, twisted or bent.

810.5.2.2 The "W" beam type safety barrier shall consist of a steel post and a 3 mm thick "W" beam rail element, spaced away from the posts. The steel post and the blocking out spacer shall both be channel section of 75 x150 mm size 5 mm thick. The rail shall be 70 cm above the ground level and posts shall be spaced 2 m center-to-center.

The thrie beam safety barrier shall have posts and spacers similar to the ones mentioned above for "W" beam type. The rail shall be placed at 85 cm above the ground level. This barrier has a higher initial cost than the "W" beam type but is less prone to damages by vehicle collisions especially for shallow angle impacts.

The "W" beam, the thrie beam, the posts, spacers and fasteners for steel barriers shall be galvanized by hot dip process (zinc coated, 0.55 kg per square metre; minimum single spot) unless otherwise specified. The galvanizing on all other steel parts shall conform to the relevant IS Specifications. All fittings (bolts, nuts, washers) shall conform to the IS:1367 and IS:1364. All galvanizing shall be done after fabrication.

810.5.2.3 Concrete for bedding and anchor assembly shall conform to Section 1700 of these Specifications.

810.5.3 Construction operations

810.5.3.1 The line and grade of railing shall be true to that shown on the plans. The railing shall be carefully adjusted prior to fixing in place, to ensure proper matching at abutting joints and correct alignment and camber throughout their length. Holes for field connections shall be drilled with the railing in place in the structure at proper grade and alignment.

810.5.3.2 Unless otherwise specified on the drawing, railing steel posts shall be given one shop coat of paint (primer) and three coats of paint on structural steel after erection, if the sections are not galvanized. Any part of assembly below ground shall be painted with three coats of red lead paint.

810.5.3.3 Splices and end connections shall be of the type and designs specified or shown on the plans and shall be of such strength as to develop full design strength of the rail elements.

810.5.4 Installation of posts

810.5.4.1 Holes shall be dug or drilled to the depth indicated on the plans or posts may be driven by approved methods and equipment, provided these are erected in proper position and are free from distortion and burring or any other damage.

810.5.4.2 All post holes that are dug or drilled shall of such size as will permit proper setting of the posts and allow sufficient room for backfilling and tapping.

810.5.4.3 Holes shall be backfilled with selected earth or stable materials in layers not exceeding 100 mm thickness and each layer shall be thoroughly tamped and rammed. When backfilling and tamping are completed, the posts or anchors shall be held securely in place.

810.5.4.4 Post holes that are drilled in rock and holes for anchor posts shall be backfilled with concrete.

810.5.4.5 Posts for metal beam guardrail on bridges shall be bolted to the structure as detailed on the plans. The anchor bolts shall be set to proper location and elevation with templates and carefully checked.

810.5.5 Erection

810.5.5.1 All guard rail anchors shall be set and attachments made and placed as indicated on the plans or as directed by the Engineer.

810.5.5.2 All bolts or clips used for fastening the guardrail or fittings to the posts shall be drawn up tightly. Each bolt shall have sufficient length to extend at least 6 mm through and beyond the full nut, except where such extensions might interfere with or endanger traffic in which case the bolts shall be cut off flush with the nut.

810.5.5.3 All railings shall be erected, drawn and adjusted so that the longitudinal tension will be uniform throughout the entire length of the rail.

810.5.6 End treatment for steel barrier

810.5.6.1 End treatments shall from an integral part of safety barriers which should not spear, vault or roll a vehicle for head-on or angled impacts. The two end treatments recommended for steel barriers are “Turned-down-guardrail” and “Anchored in back slope”.

810.5.6.2 Turned-down guardrails have the “W” or thrie section reduced from full height to ground level with a gentle slope over a distance of 8 to 9 m. The turned down rail is intended to collapse on impact, allowing the vehicle to pass over it without becoming airborne or unstable. In order to locate the barrier terminal away from the traveled way and to minimize drivers’ reaction to hazard near the road by gradually introducing a parallel barrier installation or to transition a roadside barrier nearer the roadway such as a bridge parapet or a railing, the turned down rail should be flared away from the roadway. Suggested flare rates depending upon the design speed and type of barrier are given in Table 800-14.

Table 800-14 Suggested Flare Rates

Design speed in km per hr	Flare rates	
	Rigid barriers	Semi-rigid barriers
100	17:1	13:1
80	14:1	11:1
65	11:1	9:1
50	8:1	7:1

The posts in the end treatment should have the same cross section as provided in the main barrier.

At road cross sections in cutting or if the road transitions from cut to fill, the barriers can be anchored in back slopes. The back slope covering the anchored portion of the barrier should be graded flat, with side slopes preferably not steeper than 10:1. The anchored portion should develop a tensile strength in the rail element to prevent the rail from pulling out of the anchorage. The barrier can also be anchored in an earth beam specially constructed for this purpose provided the new beam itself is not a hazard to the traffic. The earth beam should be made impervious to erosion. No flaring is to be provided for a "Turned-down-guardrail" end treatment.

810.5.7 Tolerance

The posts shall be vertical with a tolerance not exceeding 6mm in a length of 3 m. The railing barrier shall be erected true to line and grade.

810.5.8 Measurements for payment

810.5.8.1 Metal beam railing barriers will be measured by linear metre of completed length as per plans and accepted in place. Terminals/anchors of various types shall be paid for by numbers.

810.5.8.2 No measurement for payment shall be made for projections or anchors beyond the end posts except as noted above. Furnishing and placing anchor bolts and/or devices for guard rail posts on bridges shall be considered incidental to the construction and the costs thereof shall be included in the price for other items of construction.

810.5.8.3 No measurement for payment will be made for excavation or backfilling performed in connection with this construction.

810.5.9 Rate

The Contract unit rate shall include full compensation for furnishing of labour, materials, tools, equipments and incidental costs necessary for doing all the work involved in constructing the metal beam railing barrier complete in place in all respects as per these Specifications.

811 ROAD TRAFFIC SIGNALS

811.1 General

The traffic signal, its configuration, size and location shall be in accordance with IRC:93 and IS:7537 and as shown in the drawings or as directed by the Engineer. Prior to installation of signals, the Contractor shall submit to the Engineer, for approval, detailed proposals showing the signal type, sizes, paint and structural details of the signal posts including control system.

811.2 The traffic signals shall have a complete electronic mechanism for controlling the operation of traffic with an auxiliary manual controller. The time plan of signals shall be as per drawing and shall be modified as directed by the Engineer.

811.3 Materials

The various materials and fabrication thereof shall conform to the following:

811.3.1 **Signal foundation :** The signal foundation shall be constructed as per Specifications given in Clause 13 of IRC:93 or as shown in the drawings.

811.3.2 **Construction requirements :** The construction requirements for post, signal head assembly, signal head, optical system, lamp and holder, visor, post, supports for overhead mounted signals, equipment housing, locks, inter-connecting cables, earthing, mains termination, controller electrical components, etc. shall conform to IS:7537 unless otherwise stated in IRC:93. The post shall be painted and protected as per Clause 3.7 of IS:7537.

811.3.3 **Optical requirements :** The shape of all signal lenses shall be circular and shall be of specified colour and size and as shown in the drawing. Quality of lenses, arrangements of lenses, illuminations, visibility and shielding of signals shall be as per relevant Clauses of IRC:93 and IS:7537.

812.4 Tests

Tests shall be carried out on all components of traffic signals including tests on complete system for its performance as per relevant Clauses of IRC:93 and IS:7537.

811.5 Maintenance of Traffic Signals

It shall be the responsibility of the Contractor to provide for maintenance of the signal section system throughout the warranty period for at least five (5) years after installation and as per Clause 18 of IRC: 93.

811.6 Measurements for Payment

The measurement for traffic signalization system shall be by unit for complete work as specified and as per drawing for complete road junction.

811.7 Rate

The Contract unit rate for the traffic signalization system as a whole shall be payment in full compensation for furnishing all labour, materials, tools, equipment for preparing, supplying, fixing at site, testing and maintenance throughout warranty period and all other incidental costs necessary to complete and maintain the work to these Specifications.

812 TRAFFIC CONTROL AND SAFETY DEVICES IN CONSTRUCTION ZONE

812.1 General : Traffic Control Devices in the construction zone comprise signs delineators, traffic cones, drums, barricades, longitudinal barriers, warning tapes, flagmen, reflective jackets, headgears.

812.2 Signs : Traffic signs shall be in accordance with IRC:67:2001 and in accordance with IRC:SP:55:2001. Its material and other requirements shall be in accordance with Clause 801 of these Specifications.

812.3 Delineators : Delineators in constructions zone are in form of vertical posts, cones, traffic cylinders, tapes, drums etc. Vertical posts shall be in accordance with the provisions contained in IRC:79-1981.

812.4 Traffic Cones

812.4.1 Traffic cones may be of height 500 mm, 750 mm and 1000 mm, and 300 to 500 mm in diameter or in a square shape. They shall be of brilliant red/orange/yellow, ultraviolet stabilized colour for maximum visibility and fade resistance under all weather conditions and ambient working temperature of -30ºC to +140ºC. The material shall be Linear Low Density Polyethylene (LLDP), plastic or rubber so that there is no damage to the vehicle when they are stuck. Cone and base are to be of one continuous layer to prevent tearing and base separation They should be non-crushable/flexible/tear resistant and UV stabilized and made from non-fading colours. They should return to their original shape in

just 20 seconds after being crushed. The bases of cones shall be loaded with ballast (but they should not present a hazard if the cones are inadvertently struck) or anchored to check their being blown away. Their base should be designed for easy stacking without sticking . They may have retro reflective white band and mounted flashing warning light for enhanced night visibility. All traffic cones shall conform to BS:873 (Part 8) 1985 Catalogue A and the provisional European Standard EN 13422.

812.4.2 The measurement shall be for each piece and payment for each piece.

812.5 Drums

812.5.1 The drums shall be of size 800 mm to 1000 mm in height and 300 mm in diameter. They shall be constructed of lightweight, flexible, and deformable materials of LLDP or plastic so that no damage is caused to the vehicle when stuck. Steel drums shall not be used. They may be of bright red, yellow or white colours. They should be portable enough to be shifted from place to place within a temporary traffic control project to accommodate changing conditions but would remain in place for a prolonged period. The markings on drums shall be horizontal, circumferential, alternative orange and white retro reflective stripes 100 to 150 mm wide. Each drum shall have a minimum of two orange and two white stripes. Any non-retro reflective spaces between the horizontal orange and white stripes, shall not exceed 50 mm wide. Drums shall have closed tops that will not allow collection of roadwork or other debris. Drums should not be filled with sand, water, or any material to an extent that would make them hazardous to motorists, pedestrians, or workers. When they are used in regions susceptible to freezing, they should have drainage holes in the bottom so that water will not accumulate and freeze, causing a hazard if struck by a motorist. Ballast shall not be placed on top of drum.

812.5.2 The measurement shall be for each piece and payment for each piece, for providing and maintenance at site as per the direction of the Engineer.

812.6 Barricades : The barricades may be portable or permanent. Barricades may be of wooden, metal or other suitable material panels. They shall be stable under adverse weather conditions and appear significant but not to cause damage to the vehicle if they are stuck. They can be classified in 3 types, namely Type-I, Type-II and Type-III. Type-I and Type-II are portable and Type-III permanent. Because of their vulnerable position and the hazard they could create, they should be constructed of lightweight materials and should have no rigid stay bracing for A-frame designs.

812.6.1 Type-I and Type II barricade : The rail/panel length shall be 2000 mm to 2500 mm for Type I and 1000 mm to 1200 mm for Type II barricade. The width of rails shall be 200 mm to 300 mm. The rails shall be painted in alternate yellow and white stripes of 150 mm width each. Sloping away at an angle of 45° in the direction of traffic. The support shall be on a “A-Configuration” or otherwise at the top to permit convenient folding and

staking for transportation. Their stability be improved by ballasting. On highways or in other situations where barricades may be susceptible to overturning in the wind, sandbags should be used for ballasting. Sandbags may be placed on lower parts of the frame or stays to provide the required ballast but shall not be placed on top of any striped rail. Barricades shall not be ballasted by heavy objects such as rocks or chunks of concrete.

812.6.2 Type-III barricade : Type-III is the permanent type and may be made of wood, metal or other suitable material. The typical configuration shall include 3 or more panels/rails, of minimum 1000 mm length (maximum length as per site requirement) and 300 mm width each, painted with alternate yellow and white stripe of 150 mm width flopping at an angle of 45°. They shall be supported and secured on 2 or more vertical supports of same material. On highways or in other situations where barricades may be susceptible to overturning in the wind, sandbags should be used for ballasting. Sandbags may be placed on lower parts of the frame or stays to provide the required ballast but shall not be placed on top of any striped rail. Barricades shall not be ballasted by heavy objects such as rocks or chunks of concrete.

812.6.3 Application

812.6.3.1 Type I or Type II barricades are to be used in situations where traffic is maintained through the temporary traffic control zone. They may be used singly or in groups to mark a specific condition, or they may be used in a series for channelizing traffic. Type I barricades normally would be used on conventional roads or urban streets and arterials. Type II barricades have more retro reflective area and are intended for use on highways and expressways or other high-speed roadways.

812.6.3.2 Type III barricades be used for road closure and may extend completely across a roadway or from kerb to kerb. Where provision is made for access of authorized equipment and vehicles, the responsibility should be assigned to a person to ensure proper closure at the end of each work day.

When a highway is legally closed but access must still be allowed for local traffic, the Type III barricade should not be extended completely across a roadway. A sign with the appropriate legend concerning permissible use by local traffic shall be mounted.

Signs may be erected on barricades, particularly those of the fixed type, that offer a most advantageous facility for this purpose. The ROAD CLOSED and DETOUR or ARROW signs, and the large arrow warning signs, for example, can be mounted effectively on or above the barricade that closes the roadway.

812.7 Longitudinal Safety Barriers

812.7.1 Longitudinal channelising barricades are light weight channelising devices that can be used singly as Type-I, II or III barricades, or connected so that they are highly

visible and have good target value. They should be inter locked to delineate or channelise the traffic flow and mark the work zone. The inter-locking barricade wall should not have gaps that allow pedestrians or vehicles to stray from the channelising path. Longitudinal channels barricades are located adjacent to traffic and therefore, are subject to impact by errant vehicles. Because of their vulnerable positions, longitudinal channelising barricades should be constructed of light weight materials and be crash worthy. They shall be of high density polyethylene, non-fading, and high impact and U.V. resistant. They shall be of orange, white or custom colors. Their size should be minimum 1500 mm in length, 1000 mm in height, 600 mm in width. They could be filled with water through an aperture on the top and emptied by removing a plug at the base.

On roads with low speed traffic, GI sheets material could be considered for longitudinal barricades. They shall be firmly secured to vertical support system with no sharp edges to pose any hazard when struck. Their configuration shall be as per the drawing or as directed by the Engineer.

812.7.2 Measurement shall be per running metre of longitudinal barrier and payment for the running metre of complete job of providing, installation and maintenance at site as per the drawing/direction of the Engineer.

812.8 Flagman

812.8.1 The flagmen or flaggers shall be deployed where :

- Workers or equipment intermittently block an unprotected traffic lane,
- One lane is used for two directions of traffic,
- It is considered necessary to guide, warn or control traffic is considered necessary.

The flagman should be alert, intelligent and capable to effectively perform the assigned duties. Flagman shall be provided with hand signaling devices such as flags and sign paddles. Flagmen must be provided with and must wear warning garments, safety headgear, footwear and gloves for their protection and for conspicuity, while flagging. Warning garments worn at night must be of reflective material. Flags for signaling shall be minimum 600 mm by 600 mm and made of good red cloth and securely fastened to a staff of approximately of 1 m. in length. Sign paddles should be at least 600 mm wide provided with a rigid handle. The background colour of STOP should be red and its shape shall be octagonal conforming to IRC:67. The word STOP would be in white colour. Background of SLOW sign should be yellow with black letters and borders.

812.9 Reflective Clothings

812.9.1 In the work zones and construction sites, all the workers, supervisors and inspecting officers shall wear high visibility fluorescent clothings with retro reflective material,

so that their presence is conspicuous from a distance of 300 m. Clothings may be in form of vests, T-shirts, jackets, pants and raincoats etc., depending upon weather conditions and ease of usage. They shall be of bright colours of fluorescent red-orange or fluorescent yellow-green.

812.9.2 The reflective clothing's shall have reflective bands of width appropriate for the garments viz. vests, T-shirts, jackets, pants and raincoats. It shall have 360º visibility with at least one retro reflective band encircling the torso, There shall be appropriate separation distances of vertical and horizontal bands placed on torso, sleeves and trouser areas. The garment shall be free of roughness and sharp edges so as not to cause excessive irritation and the wearer should get the best possible degree of comfort and protection.

812.9.3 The reflective clothing shall meet the requirements of standards given in IS:15809-2008 or EN 471:2003 The material shall be tested for colour and luminance, colour fastness with cracking, perspiration, laundering and UV light exposure. The material shall meet the requirements of brightness after rainfall performance, temperature variation, abrasion resistance, flexing, cold folding and variation in temperature.

812.9.4 Measurement shall be for the unite piece of clothing and payment for providing and maintaining at site as per direction of the Engineer.

812.10 **Personal Protection Equipment for Workers :** All the workers, exposed to moving roadway traffic or equipment in road construction zones shall wear high-visibility safety apparel, headgear, boots, gloves and other protective gears for their protection. The safety apparel shall be in accordance with Clause 813.9. The safety headgear or protective helmet shall protect the wearer against falling objects and possible serious injury. It shall address requirements of shock absorption, resistance to penetration, flame resistance, chin strap anchorages, comfortable wearing and shall meet the requirements of IS:2925 or EN 397. The safety shoes or boots shall provide personal protection from any possible hazard posed by the activity being done and provide comfortable wearing without giving any hindrance in the expected tasks . The work gloves shall provide protection against any personal injury that could be caused by the activities to be performed and comfort in wearing without giving any hindrance in the expected tasks. If the worker is to be exposed to dust in the work zone, he shall have respiratory protection by dust mask meeting the requirements of IS:9473-2008. Depending upon the task, workers engaged in welding operations shall have eye protection through passive welding sheet meeting the requirements of EN 175 or auto darkening sheet meeting the requirement of EN 379 / EN 169.

813 TRAFFIC IMPACT ATTENUATORS

813.1 The work shall include configuration, furnishing and installing traffic impact attenuation devices at hazardous locations (for example gore areas between diverging

roadways) conforming to the details shown in the drawings/plans or as directed by the Engineer; so as to act as energy observers. The traffic impact attenuators or crash cushions shall be installed for speeds greater than 50 kph . They may be composed of sand barrels or of ‘w’-beam fender panels supported by diaphragm with trigger mechanism.

813.2 Sand Filled Impact Attenuators

813.2.1 The system shall consist of a group or series of free standing plastic barrels configured in increasing weights from the impact point towards the object. The array shall be designed to transfer the vehicle’s momentum to the increasing masses of sand in the barrels and to provide a gradual deceleration. Each barrel is to be designed with a specific weight of unbagged sand to absorb the energy of an errant vehicle. The lighter barrels shall be placed near the front of arrays to gradually slow the smaller vehicles. Heavier barrels shall be placed further back in the array to slow the larger vehicles. The standard module weights are 90 kg, 180 kg, 315 kg, 640 kg and 950 kg, as recommended by AASHTO. The axis of symmetry of the arrays should be directed along the most likely direction. Approach for an arrant vehicle for gore areas could be back towards the intersection of the edges of pavement. For roadside hazards, the angle between access of the array and the edge of the travelled way should not 10°. Obstacles in narrow median should be shielded on both ends and the modules placed on the ends (to shield opposite direction traffic) should be placed flushed with down stream edge of the obstacle to avoid wrong way hits. The modules should be placed on a concrete or asphalt surface with maximum slope of 5 percent in any direction. Each barrel’s location and weight of sand should be carefully spray painted on the surface at the position that will be covered by the barrel to ensure that the array will be correctly reconstructed after an accident.

813.2.2 The total length and width of the array shall be designed depending upon the expected speed of approaching vehicle. The typical lay out for approach speed of 100 kph would have total length of 10 m, width of 2.5 m accommodating 14 barrels arranged in 9 rows with one barrel in first 4 rows and 2 barrels in next 5 rows. The Contractor shall furnish a copy of the manufacturer’s installation instructions for whatever particular brand of sand-filled impact attenuator is to be used. The sand-filled impact attenuator arrays, shall be inspected to ensure that the array is set up as shown in the standard plans and filled in accordance with the manufacturer’s recommendations. Sand barrels are essentially one-hit systems requiring complete replacement of impacted barrels. Their use, therefore, is suitable at sites where impact frequency is expected to be low. The arrangement shall be first designed and the layout drawing got approved by the Engineer.

813.3 Proprietary Attenuator System

The Proprietary Attenuator Systems essentially comprise a series of w- beam fender panels supported by diaphragms with a trigger mechanism at nose, which, when hit, releases a ‘front assembly’ to absorb the energy of impact. When impacted, the system shall telescope rearward to absorb the energy so as to bring the errant vehicle to a controlled stop. The

refurbishment shall involve the replacement of damaged unit with repair done, off site. The contractor/supplier of such system shall furnish the certificate that the system to be installed has been tested in accordance with the NCHRP 350 and performs effectively at design speeds up to 100 kmph.

813.4 Measurement and Payment

The traffic impact attenuator system shall be measured and payment made for design and installation of the system as complete job at each location.

814 SEMI AUTOMATIC TOLL COLLECTION SYSTEM

814.1 The Integrated Semi Automatic Toll Collection System shall comprise following main subsystems:

- i) Automatic Vehicle Counter cum Classifier (AVCC)
- ii) Automatic Boom Barrier
- iii) Contactless Smart Card Systems
- iv) Ticket Printer
- v) User Fare Display unit
- vi) Close Circuit Television System (CCTV)
- vii) Lane Controller
- viii) Traffic Light System
- ix) Intercom System
- x) Over Head Lane Signs
- xi) Integrated Toll Management Software

All equipment shall have built - in or external surge protection devices.

814.2 AVCC System

814.2.1 General

The AVCC system shall be able to distinguish between the categories of vehicles using the highway and as defined by the Ministry's Toll Rules. This class information shall be transmitted to the Lane Computer on completion of the post Automatic Vehicle Classification (AVC). The Lane Computer shall check that this information matches the classification entered by the toll collector. If there is a discrepancy between the two classifications, the Lane Camera shall be triggered to capture a digital image of the vehicle together with

details of the class discrepancy message, transaction number with its date and time, lane number and toll collector. The digital image and discrepancy information shall be communicated to the supervisory console for further processing by the toll supervision staff. In case of network or Lane computer failure, the AVCC system shall function independently and feed data directly to the Plaza Server and the system shall be able to detect the vehicle moving in wrong direction. The system shall also assist in auditing the toll collection operation. It shall be in modular unit with capability for various modules and functions to perform independently at different levels of toll collection operation. The Central AVCC data base system shall be part of this audit function. It shall be a stand alone device with control access where the data cannot be changed or altered in any way. The reports from this system shall assist in identifying problems with operations, fraud or over/ under collection of tolls. This central AVCC database System shall be able to operate independently of the Toll Lane System, even if the Toll Lane Controller is non operational. Any new technology, meeting the requirements specified in these Specifications should not be excluded.

814.2.2 Technical requirements

Each lane shall be equipped with an AVC controller (different from the lane controller) interface to classification sensors. The classification sensors can be any or combinations of the following types:

i) Fiber-optic treadles

ii) Laser classifiers

iii) Optical height sensors

iv) Optical axle counters

v) Infrared Light curtains

vi) Magnetic Sensors

vii) Resistive Sensors

AVCC processing unit shall be a real-time processing unit, shall be the trigger source for Lane Camera system and shall have standby power supply capable of operations for a period of at least 4 hours. The AVC controller should be metallic, vandal-proof with IP 65 protection. It shall have System accuracy (calculated on a base of 10,000 vehicles) :

a) For vehicle counting : 99% minimum.

b) For vehicle classification : 98% minimum.

814.3 Automatic Boom Barrier

814.3.1 General

The barriers are to be used to control the traffic through the lane. The operation of boom barrier shall be linked to the lane computer and shall allow the vehicle to pass through after a successful financial transaction. The system shall consist of a fixed housing and a movable arm. The boom shall be of 3000 mm length for a normal lane and more than 3500 mm for extra wide lane. The housing shall contain the motor and control units and shall be installed on the left side of the lane. The boom barrier should be electrically operated barrier gate for Toll Lane application. The barriers shall have presence detectors independent to the AVC system to prevent barrier arms coming down on vehicles while passing. This shall be in the form of infrared units, dedicated embedded loops or any other sensors. The finish of its housing may be Powder Coated Orange, RAL 2000 and that of the boom with powder Coated White RAL 9010 with reflective strips. All housing and internal parts shall have rust and corrosion free metals or alloys of high strength with suitable epoxy coating as applicable. The Housing base frame shall be of Stainless Steel so as to protect the housing from rusting from the bottom.

814.3.2 Technical requirement

The power supply shall be through 230+/-10%V AC, 50Hz with 100 percent duty cycle. Its Logic Control shall be with Technology to ensure that opening and closing timings remain constant under variation of wind and speed. It shall have smooth landing of boom without swaying at the end positions. The response time shall be 1.5 seconds, for boom length of upto 3000 mm and 2 sec. for boom length more than 3500 mm. The mean time before failure (MTBF) shall be 5 million cycles (1 Cycle = 1 open and close). It should be able to operate between the temperature range of -5^{o}C to 55^{o}C.

814.4 Lane Camera

814.4.1 General

The camera installed at convenient location shall be capable of capturing images of the following vehicles:

a) In case of class discrepancy between the class detected by the AVC and that entered by the toll collector

b) Exempt users

c) Vehicles with Smart card

d) All transaction of vehicle with special events

e) Offending vehicles

f) When the alarm footswitch is activated by the toll collector.

814.4.2 System Configuration

The camera should be installed at convenient location to capture images of the vehicles It shall produce clear images of the front view along with the number plates of the vehicles even during night. The resolution of the images should be such that the registration number of the vehicles can be easily read. The camera should have waterproof housing with a hood to protect from direct sunlight. The protection shall be in accordance with IP65. The stand for the camera shall be made in steel tube that will not swing or twist under gutter speed of strong wind.

814.5 Smart Card System

814.5.1 Contactless smart card readers/writers

814.5.1.1 General

The Contactless Smart Card Readers/Writers are used for managing electronic Toll Collection in conjunction with a compatible Contactless Smart Card. The Contactless Smart Card Readers/Writer is linked to a micro-controller or a PC which is typically the lane computer. It allows the vehicle to pass through after a successful financial transaction. Card reader/writer shall be “single-package” type, combining electronics and antenna in one package.

814.5.1.2 Installation requirement

The Contactless Smart Card Readers/Writers shall be installed on the right side of all the lanes of the Toll Plaza. The orientation of the Contactless Smart Card Readers/Writers shall be wall mounting type, to be at a suitable height on the toll booth wall, to accommodate all types of vehicles e.g. separate readers for trucks/buses and cars/jeeps. This is to ensure that a successful ‘Readers/Write’ is achieved with a Contactless Smart Card. Readers/Writers.

814.5.1.3 Technical requirements

The reader shall have the ability to read the smart card from a distance, ranging from 0 cm to 10 cm with a transaction time of less than 0.5 seconds for read/write. Contactless Smart Card Readers/Writers shall be wall mounting type and all transactions shall be secured with modern and industry standard cryptographic techniques or those based on DES/3DES mechanisms to resist fraud and to deter theft or misuse. The reader/writer shall conform to ISO Standards: 14443A and shall be sealed to a NEMA 4/IP65. It should have transmit frequency of 13.56 MHz. The operating temperature of the Smart Card Readers/Writer should be -5^{o}C to +55^{o}C and operating humidity of up to 95 percent non-condensing.

814.5.2 Contactless smart cards

814.5.2.1 General

The Contactless Smart Card is used for storing money value for the purpose of Toll Collection in conjunction with a compatible Contactless Smart Card Readers/Writers. The Contactless Smart Card allows the Readers/Writers to increment/decrement user fee from the stored money value. It allows the vehicle to pass through after a successful financial transaction. The Contactless Smart Card, the card Readers/Writers shall be in a single technology configuration. The Smart Card shall be able to store the money value in prepaid mode.

814.5.2.2 Technical requirements

The card shall meet the ISO 14443A standards for contactless smart cards. The memory of the smart card shall be >=1KB. It shall be warranted against defects in materials and workmanship for 3 years. The Operating Temperature of the Smart Card should be -10ºC to 60ºC.

814.6 Close Circuit Television (CCTV) System

814.6.1 General

The System shall be provided to monitor the activities of toll collection booth operations in the toll plaza. It shall comprise Video Camera and Video Camera Housing at the toll Plaza and 42'' LCD Monitor and Digital Video Recorder (DVR) at the control centre. The Video Cameras shall be conveniently mounted so that full view of the Toll Plaza and the booth operations are captured.

814.6.2. Technical requirements

The Video Camera shall be of dome type to avoid pilferage, be resistant to vandalism and be weather-proof. The mounting and equipment housing shall be able to withstand adverse weather conditions The camera shall provide a minimum of 520 TV lines horizontal resolution. The camera shall provide a useable picture at a minimum illumination of 0.02 Lux. The weighted signal to noise (SN) ratio shall be greater than 50 dB at 1.0 V p-p, 75 ohms. The Cameras shall have MTBF (Mean time between failure) of at least 50,000 hours of operation.

814.7 Digital Video Recorder (DVR)

The Digital recorder shall be stand alone and have the facility to record images on the hard disk and also on external recording devices such as DVD, Hard Disk etc. The digital

Video Recorder shall have enough data storage capacity to store video of 15 days from all the cameras and shall have interface to archive the data on to the DVD/Tape for back-up. The DVR shall have sufficient video signal inputs to cater for all cameras. It shall have Capability alarm/event based recording and the facility for high speed searching based on inputs such as date, time, etc. The Digital recorder shall have functionality to display multiple video images simultaneously on a single Monitor/Screen.

814.8 Lane Controller

814.8.1 General

The Lane Controller shall be provided to control and monitor all the sub systems of the toll lane. It shall consist of CPU and power supply, Data Communication ports, Digital I/O port, Circuit breakers, Terminal blocks, Relays LAN port, IP 65 enclosure with high security locking mechanism. All the peripheral devices in the lane shall be hardwired to the Lane Controller.

814.8.2 Technical requirements

The system shall be modular with Input/Output Card having adequate channels catering to interfacing of all the peripherals devices with a provision for adding extra two devices. The system shall be housed in a metallic enclosure and installed inside the toll booth. All the peripheral devices in the lane shall be hardwired to the Lane Controller.

814.9 User's Fare Display Unit

814.9.1 General

The Fare Display Unit shall be in the form of a variable message sign, controlled automatically by the lane computer, to indicate the category of the vehicle and the amount payable by the road user. The system shall be LED based. It shall be installed outside the booth, near the payment window so that the road user will have clear view of the fare payable.

814.9.2 Technical requirements

a)	Power Supply	:	220V/50 Hz AC
b)	Communication	:	RS232
c)	Operating Temperature	:	-10°C to + 55°C
d)	Protection	:	IP 65
e)	LED Reliability	:	100,000 hrs

814.10 Traffic Light System

814.10.1 General

LED based light signal, installed at the toll lane towards the exit side shall be connected to the lane controller. The traffic sign glowing red would indicate that the motorist has to stop and pay the user fee. After successful transactions, the traffic sign would turn green to indicate that the motorist can proceed. Traffic lights shall be installed on a pole of about 2 m above the road surface on the right side of each lane. The Contractor shall decide the appropriate height taking into account other equipments to ensure clear/unobstructed visibility and control through lane controller. The system shall work in synchronization with the boom barrier and shall have in-built night dimming function.

814.10.2 Technical requirements

a) Size of the display : Approx 200 mm diametre with sun visor

b) LED : Industry standard, Red and Green

c) Housing : Corrosion resistant material

d) Environmental protection : IP 65

e) Intensity : Day light visibility > 1000 mcd for Red, >1600 mcd for Green

f) Operating temperature : -10^{o}C to + 65^{o}C

814.11 Lane Communication System

Voice communication installed in the toll booths shall provide "hands free" two-way verbal communication between the supervision staff in the toll control room and the toll collectors. The toll collector shall be able to attract the attention of the Supervisor in the control room by pressing a single button on the intercom slave unit in the toll booth. The equipment shall also have the facility to allow the supervision staff to monitor communication in the toll booth between the toll collector and the user or between any of the tollbooths without alerting the toll collector. The voice communication system shall operate independently of the Lane Computer system. It shall also be implemented in various rooms of the plaza building and at building access points. Two-way communications shall be possible as soon as the Supervisor responds by selecting the appropriate lane button on the Master Communication unit. One-way communication shall be possible from the Control Room intercom to all lanes simultaneously (broadcast).

814.12 Overhead Lane Signs (OHLS)

814.12.1 The overhead lane signs OHLS shall be mounted on the leading edge of the canopy covering the toll lanes above the centre of the lane to indicate to the User whether

the toll lane is open or closed for the processing of vehicles. A red cross signal would indicate that the lane is closed, whilst a green arrow would indicate that the lane is open to traffic.

814.12.2 Technical requirements

The OHLS shall be made of green and red LEDs. Signs shall be sufficiently bright and directed to indicate to a motorist approaching the toll plaza, at a distance of 250 m on a bright cloud free day that lanes are available for use. The cross and allow aspects shall be larger than 300 mm. The sign shall be fitted with a sun-hood to screen the effect of the sunlight. The enclosure of the OHLS shall be constructed from a corrosion resistant material. The enclosure shall have an IP 65 rating and be ventilated to dissipate internal heat. The system shall have night dimming function.

814.13 UPS System

UPS system shall be supplied for individual lanes and plaza systems separately. Each UPS system shall be designed for 125 percent of the total connected load. The power supply to all electronic equipment (indoor and outdoor) shall be fed from UPS which shall have minimum 2 hours backup. The power budget calculation is to be submitted to the Engineer.

814.14 Violation Alarm

The siren operates in conjunction with a violation and acts as a warning device. The purpose of the siren is to alert the plaza staff of a run-through through the lane. Visual indication is via a strobe light. It shall meet the following requirements :

i)	Technology	:	Motor driven
ii)	Audible rating	:	112 dB at 1 m
iii)	Hearing distance	:	500 m
iv)	Environmental Protection	:	IP 65

814.15 Computer Hardware

814.15.1 **Plaza server** shall have following minimum Specification :

1) Intel Xeon 3.0 GHz or higher with Intel EM64T/1 MB Cache/ 800 MHz FSB
2) 2 GB ECC DDR2 RAM upgradeable to 12 GB
3) Dual Channel U320 SCSI Controller

4) 6x36 GB (10K rpm) HDD, Hot-pluggable, with RAID-5 Support

5) CDRW – DVD Combo Drive

6) Dual Gigabit 10/100/1000 Ethernet

8) Redundant Power Supplies, Redundant Fans

9) Anti-virus pre-loaded

10) Server Management Software – with remote management features onboard

11) 20/40 GB DAT Drive

12) Certifications: ACP V1.0 B Compliant PCI 2.2 Compliant, PXE Support, WOL support, Microsoft Windows 2000/2003, Linux, PCI-X1.0 Compliant

13) Operating Conditions:Operating Temperature Range: 0ºC-50ºC Relative Humidity: 20 percent - 90 percent, non-condensing

14) AC Voltage : 207V AC to 253V AC @ 47-63Hz

814.15.2 Bar code reader

The bar code reader shall be used to scan unique identification bar codes imprinted on media such as paper and plastic medium such as smart cards etc.The bar code reader shall be equipped with easily visible LEDs and audible beeps that indicate the scanner's operation status. The barcode reader shall have a rugged protective boot with an adjustable stand and be mounted to a countertop or be left free standing for handheld scanning. The barcode readers shall conform to IS:14700: Part 6: Sec 3; 2002. The bar code reader shall be IP54 protected.

814.15.3 Receipt printer

The receipt printer shall be a compact thermal printer able to print, as a minimum, toll payment receipts (text and graphics) and barcodes. The receipt printer shall use thermal fixed head technology. The print speed shall not be less than 150 mm/s for both text and graphic and at a minimum resolution of 203 dpi (8 dots/mm). It shall be able to support paper thickness of 75 - 80 GSM. The receipt printer shall support programmable English and Hindi fonts and graphics, including Barcodes of at least Code 128 format. The receipt printer shall have an automatic cutter with a self sharpening ceramic rotary knife. The receipt printer shall be robust for use in a toll booth environment where there is heavy usage and possible dust and exhaust from vehicles. The auto cutter shall have a reliability of at least 1.5 million cuts. The receipt printer head shall have a Mean Cycle between Failure (MCBF) of at least 50 million print lines. The receipt printer shall have a Mean Time between Failure (MTBF) of at least 360,000 hours. The receipt printer enclosure shall be IP54 rated.

814.15.3 Toll Management System (TMS)

The Toll Management System (TMS) shall be responsible for processing the data into information that will be used to verify toll transactions, provide toll collector control, cash-up and performance facilities, and shall include a host of management tools and reports for the effective administration of the toll operation. The TMS shall also assist in auditing the toll collection operation. It shall be a modular unit with the capability for various modules and functions to perform independently at different levels of the toll collection operation. The TMS shall have various customized reports to assist in managing the toll facility, and to provide management tools to asses toll revenues. The TMS shall have financial management and traffic analysis tools to assist the operator in planning operations. The Contractor/supplier shall ensure that security updates and latest service packs, “patches” are loaded. Industry standard operating systems shall be utilized and all user licenses shall be provided. The database shall be an industry standard database and shall be supplied with all the latest service packs and patches, including user licenses.

815 ADVANCED TRAFFIC MANAGEMENT SYSTEMS (ATMS)

815.1 General

The work would cover design, supply, installation, commissioning and/or operation and maintenance of Advance Traffic Management Systems (which is one of the components of Intelligent Transport Systems - ITS). The system would include out-door equipment including emergency call boxes, variable message sign systems, meteorological data system, close circuit TV camera (CCTV) system, traffic counting and classification system and transmission system. The indoor equipment would comprise a large display board, central computer (with Network Management System - NMS), CCTV monitor system, call centre system or management of emergency call boxes housed in a control centre with uninterrupted power supply. Any new technology, meeting the requirements specified in these specifications should not be excluded. The systems shall meet following objectives

- Smooth and uninterrupted traffic flow
- Enhance road safety
- Real time information and guidance to users
- Emergency assistance round the clock
- Alerts for abnormal road and weather conditions
- Reduced journey time and inconvenience

815.2 System requirement

ATMS shall provide the following facilities to highway users:

- make emergency calls to Control Centre in case of accidents, breakdown, fire and ambulance.
- pre-warn the highway users about unusual condition on the road.

ATMS shall provide the following information/data to traffic managers for efficient and effective handling of traffic.

- information regarding location of any incident, incoming calls, help required and messages to be passed to third parties.
- Information regarding traffic congestion, speed and weather conditions.

ATMS shall provide the following controls to traffic managers:

- change the variable message signs from the Control Centre.
- mobilize the movement of ambulances, cranes & patrolling vehicles.

ATMS shall provide online recording and reviewing of the voice & visual information for record and analysis.

815.3 System Configuration

The ATMS shall have following sub-systems:

i) Emergency Call Boxes

ii) Mobile Communication System

iii) Variable Message Signs system

iv) Meteorological Data System

v) Automatic Traffic Counter cum Classifier System

vi) Video Surveillance System

vii) Video Incident Detection System (VIDS)

815.4 Availability Requirements

The inability to perform any required function, the occurrence of unexpected action or degradation of performance below the specifications shall be considered as a failure. The Mean-time-between-failure (MTBF) shall be the average operating time accumulated by

the total population of identical items between failures. The system supplier/contractor shall submit MTBF and MTTR figures. The ATMS shall have an overall system availability of better than 99 percent. The ATMS shall be considered unavailable if any of its function cannot be properly executed and when any of the following conditions persist for more than 8 hours on the entire stretch.

i) Variable Message System Failure**:** No display/Improper Display of VMS or failure of their related transmission/control system which would render the VMS inoperative

ii) Emergency Call System Failure: Failure of any three consecutive Call boxes or failure of their related transmission system which would render the call boxes inoperative.

iii) ATCC Failure: Failure of more than one ATCC or failure of their related transmission system which would render the ATCC inoperative.

iv) Met Failure: Failure of more than one Met or failure of their related transmission system which would render the Met inoperative.

v) Video Surveillance System Failure: Failure of more than two Video Cameras or failure of their related transmission/control system which would render the cameras inoperative.

vi) Video Incident Detection System Failure: Failure of more than one Video Cameras or failure of their related transmission/control system which would render the cameras inoperative.

vii) Display at Control Centre: Whenever Control Centre is unable to get display of messages initiated by the Control Centre in-charge.

In addition to the above the system shall be considered unavailable when failure of the integrated ATMS Software or its hardware persists for more than 8 hours.

815.5 Reliability Requirements

The supplier shall ensure that ATMS supplied shall comply with the following reliability requirements:

ATMS (Sub-Systems)	**Mean Time Before Failure - MTBF**
Outdoor Equipment	15,000 hours
Transmission System Equipment	15,000 hours
Control Centre Equipment	15,000 hours
Power Supply Equipment	15,000 hours

815.6 Maintainability Requirements

The Mean-Time-to-Repair (MTTR) of the ATMS to full normal operation following a failure shall be less than 8 hours all inclusive.

815.7 System Safety Requirements

The ATMS is classified as a safety related system and a minimum of CENELEC standards EN50128 software integrity level 2 shall apply. All equipment must comply with and be installed in accordance with IEC 65, IEC 364. All metal enclosures shall be provided with an earthing terminal and earthing of all equipment shall be carried out in accordance with overall earthing policy.

815.8 Environmental/Climatic Requirements

815.8.1 Indoor equipment :

Temperature (Operating)	:	0^{o}C to + 50^{o}C
Relative Humidity	:	up to 95% (non-condensing)

817.8.2 Outdoor Equipment

Temperature (Operating)	:	5^{o}C to + 60^{o}C
Relative Humidity	:	up to 95% (non-condensing)

The system and the equipment used as a minimum shall meet the following climatic and environmental requirements as specified in IS:9000 :

Tests	**Severities**
Change of Temperature (Temp cycling) as per IS:9000 (part xiv/sec1)	(i) Low Temp 0°C + 3°C (ii) High Temp 60°C + 2°C Rate of cooling and heating 1°C/m (iii) Duration for each cycle 3 hours (iv) No of Cycles 3
Damp heat (Cyclic) test as per IS: 9000 (part v/sec 2) variant 1	(i) Upper Temp 40°C + 2°C (ii) Lower Temp 25°C (iii) One Cycle 12 h (iv) Relative humidity 95 percent (v) No. of Cycles 6

Vibration (Sinusoidal) test as per IS:9000	(i)	Freq. range	10 Hz – 55 Hz
	(ii)	Vibration Amplitude	0.35 mm
	iii)	Duration of endurance for sweep	20 sweep cycles (10 Hz – 55 Hz)
	(iv)	No of axes	3 co-ordinate axis
	(v)	Duration at resonant frequency	30 min+1 min

815.9 Emergency Call Box

815.9.1 General

The apparatus is a communication medium to be installed on the highway and to be used by the road users to make alarm call to the Control Centre in case of accidents and other emergency problems on the road or any incident. The Emergency Call Boxes shall be located in pairs on opposite sides of the highway. Main ECB unit (Master) shall be located on one side and the secondary unit (Slave) on the opposite side.

815.9.2 System Configuration

The Emergency phone shall comprise loud speaker, microphone, activation button, ringing tone to indicate progress of call when button is pressed, confidence tone to indicate call is still connected when on hold, recorded message in case the line is busy and LED indication during conversation. These components shall be provided in FRP (Fibre Reinforcement Plastic)/stainless steel/Aluminium Alloy housing.

815.9.2 General requirements

The ECB shall be designed for hands free operation. It shall be identified by reflective guide sign placed approx. 10 m ahead of the ECB . It shall have a provision for mounting on a concrete base with cast-in bolts, nuts and washers and the whole shall be installed so as the persons using the instrument will normally be facing the oncoming traffic. The enclosure shall be equipped with retro reflective sticker that is clearly visible at night. The sticker shall read ‘SOS’ along with a telephone symbol. It shall have provision for the instructions of operation to be written clearly on the outside surface in two languages. Voice Logger Software shall be provided to handle and log all calls from the network. There shall be up to four programmable auto dial numbers associated with the push button. The ECB shall automatically dial subsequent numbers if the first number is busy or unavailable.

815.9.3 Technical requirements

815.9.3.1 The ECBs shall work on DC supply and operate in full duplex mode. It shall be able to operate in a noise level of up to 95 db. and suitably protected against external EMI/ESI Interference through shielding/grounding. It shall have in-built programming port/ feature for addressing. The same must be capable of being addressed using Laptop or Palmtops in fields. The ECB Central software shall use this address for identification of ECB. The ECB shall use latest components and a micro controller of adequate capacity to meet the system requirements. It shall have in-built fault diagnostics features for on-site maintenance and have extant protection against lightning. It shall be powered from the communication cable/solar panel. The solar panel and battery shall be adequately rated to support the ECB working under idle conditions and a talk time of minimum 90 minutes over 3 days in succession under worst climatic conditions. At each location one ECB shall be Master and the other Slave. The master ECB shall be equipped with fibre optic interface, solar panel, battery back-up and voice communication mechanism and shall also comply with all the requirements specified in this section for ECBs. The slave ECB shall be equipped at least with – activation button, vandal sensing mechanism, call progress indication LED, Microphone, Speakers, Handicapped operation activation – in a weather proof housing as detailed in these Specifications. The system shall detect vandalism and give audio-visual alarm at the control centre. The ECB system shall have a product support guarantee of 10 years from the manufacturer. The ECB central system shall communicate with the Central Traffic Management System and all the events and alarms shall also be displayed and stored in the Central Traffic Management server. The ECBs shall meet the specification as per the following:

i) Electromagnetic compatibility : be suitably protected against external EMI/ESI Interface through shielding/grounding.

ii) Lightning Protection : to be suitably protected.

iii) Drop and topple : BS2011 or equivalent.

iv) Enclosure : IP 65.

The equipment shall conform to all applicable electrical standards in India.

815.10 Mobile Radio Communication System

815.10.1 General

The mobile communication system shall be provided to establish voice communication on radio between the Control Centre and the emergency mobile vehicles such as ambulances, cranes and patrolling vehicles. The system shall comprise base station unit, repeater unit, mobile radio unit and control centre equipment. Its Base Station Unit shall comprise transmitter, receiver antenna switch, radio engineering terminal, radio data terminal, radio

operator terminal and power supply. Its Repeater Unit shall comprise transmitter, receiver, antenna, repeater and power supply. Its Mobile Radio Unit shall comprise transmitter, receiver, antenna, control unit and power supply. The Control Centre Equipment shall have Network Management System.

815.10.2 General requirements

The system shall cover the entire route. The system design shall be modular in concept. The system shall be compact and rugged in design having ease of maintenance and shall work satisfactorily under adverse conditions like storm, rain and vandalism resistant. The system shall neither affect functioning of other telecom equipment installed adjacent or along it, nor get affected by the presence of other equipment/systems. The Mobile Radio shall have provision for mounting the mobile set on ambulances, cranes and patrolling vehicles. The repeater station equipment and antenna shall be installed at sub centres. Each mobile unit shall have a unique address code. The system equipment shall work on re-chargeable batteries with 24 hr back-up.

The control panel of mobile unit and base station unit shall have the following features:

i) Power ON-OFF switch

ii) Emergency calling button

iii) Adjustment of loudspeaker volume

iv) Digital display

v) Functional buttons

815.10.3 Functional requirements

The modulation shall be either frequency or phase type (FSK) and shall operate in semi-duplex mode. The equipment shall have provision to eliminate collision of data. It shall have facility to configure the network for individual, sub-group or broadcast mode of operation for both selective calling and group calling operation. All components used in the assembly of equipment shall be of industrial grade specification. The equipment shall conform to ETS European standards and shall be suitably protected through shielding/ grounding against external EMI/ESI Interference, and shall be immune to RFI, ESD and lightning.

815.10.4 Technical requirements

The system shall have the facility to connect mobile to mobile, mobile to controller and controller to mobile. The system shall have the facilities for waiting calls, holds calls and transfer calls. The system shall have a facility such that the Control Centre can select between

the call modes of individual call, group/all-call and call to mobiles listed in the queue. The system shall use primary channels for calling from mobiles to the Control Centre and vice-versa whereas the secondary channels shall be used for mobile to mobile connection. The system shall have the facility to terminate the mobile to mobile connection under the following conditions:

a) One of the two parties hangs up

b) One of the two parties receives a call from the Control Centre

c) The duration of the conversation exceeds 5 minutes limit.

In case of emergency, the system shall have the facility to receive alarm calls from mobile radio. The mobile radio shall be integrated with the Fibre Optic Communication system. The system shall use frequencies to be obtained by the contractor from WPC in the complete stretch as per scope. The system shall have the provision for communication on the PSTN Network. The system shall have suitable voting system to select the better signal at base stations as well as mobile units. The system shall have provision to handle calls from/to at least 20 mobile sets. The system shall have self-diagnostic features. The system shall be protected against any damage due to power supply fluctuations, transients and surges.

815.11 Variable Message Signs

815.11.1 Function

The Variable Message Signs (VMSs) shall provide to road users the advance en-route traveler information of road conditions ahead in real time. VMS shall generally provide :

i) Advance information on incidents such as accidents, traffic diversions, incident management and notice for road work, adverse weather and road conditions and operation with lane control signals;

ii) Traveler information such as display of road construction activity in near future, messages for testing of the system and special events that affect the traffic flow;

iii) Public service announcements like messages relating to driver safety campaign.

815.11.2 Fixed VMS

Fixed VMS shall be mounted on a sturdy and aesthetically pleasing gantry structure whereby the vertical clearance of at least 5.5 m is available from the road. Safety barriers shall be provided at gantry support column(s) for their protection and for safety of road users. The concrete pedestal for support column should be flushed with ground but in no case should protrude for more than 1.5 m.

815.11.2.1 The minimum distance of VMS on expressways should be 1.5 km prior to decision point and that for National Highways it should be 1 km. The signs should be visible from a distance of 250 m. It should not be located on a curvet and on a highway sections having grade exceeding 4 percent.

815.11.2.2 There should be clear distance between existing sign and VMS. The minimum distance between road signs and VMS should be at least 250 m on expressways and 150 m on National Highways.

815.11.3 Portable VMS

815.11.3.1 Portable signs can be mounted at the back of the truck or similar vehicle. The portable VMS signs mounted on a truck could be powered by solar energy or battery and show the sign of 'men at work' and/or speed limits in the construction zone. They shall be so placed that they are effective. The placement must give adequate time to the motorists to react to the message and take corrective action. On Expressways and National Highways placement of these at 2 km prior to the decision points should be done with repetition at every 500 m. It should provide a sight distance of 300 m and should not interfere with other traffic control devices. If the portable VMS set-up and a message is not to be required for a period of next four hours or more, the sign panel should be turned away from the traffic, parallel to the road centre line. Non blank signs should be facing the drivers for an extended period.

815.11.3.2 Under no circumstances shall VMS be used for advertising of any kind. It would be in blank mode when traffic, roadway, environment or pavement conditions or public service announcements do not warrant the display of message or messages.

815.11.4 Type of messages through VMS

815.11.4.1 The average driver or motorized vehicle at high speed can comprehend two message panels. Each panel should be complete phrase and each phrase should be independent of the other. The messages should consist of :

	Type of Statement		Example
•	A problem statement	-	Road work/accident ahead
•	An effect statement	-	Delay/congestion
•	An attention statement for certain group	-	Motorist
•	An action statement	-	Take the next carriageway

815.11.4.2 Some typical messages are as given below:

- Accident Ahead, Road Closed, Take Diversion;
- 'Accident Ahead' followed by some typical messages like 'Expect Delays', Merge Right', Merge Left', 'All Traffic Exit' can be displayed.
- Maximum Speed:—————kmph
- Speed Limit Strictly enforced;
- Construction Work, Road Closed;
- Signal Ahead;
- Sharp Curve Ahead;
- Congestion Ahead;
- Bad weather conditions like 'Heave Fog Ahead', 'Poor Visibility Ahead;
- Trucks use Left Lane;
- Watch for Stopped Traffic;
- Watch your speed;
- Watch for Falling Rocks: (In the case of landslide prone areas);
- Two Way Traffic Ahead (this message can be displayed where the road section abruptly changes from four/six lane divided section to two lane bi-directional carriageways);
- No Mobile When Mobile;
- Drunken Driving Prohibited;

815.11.5 Technical requirements

The design of the system shall be modular. The system shall use LEDs/high gain Tran reflective LCDs for outdoor full sunlight. The failure of one LED module should not affect the output of any other LED cluster. Its design shall be such that the display is legible from a distance of 300 m on Expressways and from 250 m on other highways.

The equipment will comply with the following:

i)	Overall Size Board	Length minimum 3000 mm Height minimum 1800 mm Depth 200 mm

ii)	Number of Display Lines	3
iii)	Number of Characters per line	15
iv)	Height of Characters	minimum 400 mm
v)	Language	Bilingual
vi)	Contrast Ratio	> 30:1 perpendicular to the board face >10:1 at an angle of + 70° to perpendicular.
vii)	Memory	Capable of storing minimum 10 frames that can be triggered on receiving the tele-command.
viii)	Housing or other	Powder coated housing with IP54 equivalent international standard for protection easing against dust, sprayed water and winds.
ix)	Mounting	Pole mounted as gantry and or cantilever with vertical clearance of 5.5 m from the surface.
x)	Interface Standard	RS422 and RS485 interfaces with compatibility on Ethernet.
xi)	Special Features	Automatic diagnostic and reporting of failure/fault of arrays/ rows.
xii)	Additional Features and humidity sensor.	Incorporation of temperature sensor
xiii)	Luminous Intensity (LED)	> 3000 mcd
xiv)	Life of Components of VMS	> 10 years

Elaborate Fault diagnostics shall be provided as per EN 12966 or other equivalent international standards. Each pixel shall be monitored and feed back shall be provided for the health status. Minimum of following shall be provided:

i) Power Failure at VMS

ii) Processor PCB Failure

iii) LED Cluster Failure

iv) Loss of incoming message/data not properly received.

v) Temperature monitoring.

The controller unit shall provide brightness control facility. monitoring of ambient temperature of the housing. The controller shall be capable of automatically diagnosing and reporting component failure or any electronic fault. The controller shall be provided with a test port for local diagnostics via laptop. It shall be possible to perform fault diagnostics from the central control room via the software. The LED Clusters shall be mounted suitably for providing better viewing angle. Each display module shall have its own display interface to the Central processor. VMS shall be designed to comply with the following protocols:

NMCS2, MESSAGE CONTROL, TR2070D, NTCIP Version 2 or other equivalent international protocols.

815.11.6 Testing

The equipment shall be tested for functional requirements as below :

Messages shall be displayed using the central software and local terminal The fault conditions shall be simulated. Messages/fault logs shall be checked for:

a) LED FAULT

b) Communication failure

c) Power failure

d) Brightness of Pixels

815.11.7 Installation requirements

The structure on which the VMS is mounted shall be sturdy and aesthetically looking and capable of bearing wind loads up to 200 kmph. The lowest hung part of the display board shall have vertical clearance of at least 5.5 m from the road level. It shall be provided with a walkway to allow at least six persons to carry out maintenance of the VMS without obstructing the carriageway.

815.12 Transmission System

815.12.1 General

The Transmission system provides connectivity between Control Centre and outdoor equipment such as Emergency Call Boxes, Variable Message Signs, Meteorological Data System, Video Cameras, Traffic Sensors, etc. The system shall comprise Cable System, Interface System and Optical Fibre Transmission System.

815.12.2 Cable system : The system shall comprise copper cable, Backbone Optical fibre cable (for connectivity between the sub-centers and main control centre) and auxiliary

fibre optic cable for connectivity of the road side equipment to the sub-centre and Coaxial cable. The cable system along with interface equipment shall work satisfactorily under adverse conditions like storm, etc. The Optical Fibre Cable system shall interconnect with the defined optical transmission sources and also if required with associated network devices for signal transmission without any impairment. A separate and independent (auxiliary) Optical Fibre Cable system shall be used for the transmission of video signals, data signals form the equipment locations to the sub-centers where copper cable has limitations for transmission of signal

All Optical Fibre Cable shall be of TEC (Govt. of India) approved design.

The Co-axial Cable System shall provide immediate interface to carry signals from CCTV /VIDS Cameras located at strategic locations to the nearest sub centre. Optical Fibre Cable shall also be used with transmitters and receivers if the distance is large and high quality signal transmission and reception is not possible using co-axial system. The signals shall, without any impairment, be routed to the Control Centre via the sub-centers using the auxiliary Optical Fibre cable.

815.12.3 Interface system : Interface System shall comprise Sensor interface equipment, Optical fibre cable interface equipment and Control Centre interface equipment The Interface System shall cover the Copper Cable, Co-axial Cable and Optical Fibre Cable System and transmit and process the composite signals to achieve the desired reliability/availability requirement. The Interface sub-systems shall be capable of handling the composite audio, video and data signals at various interface levels and process them. The Interface sub-systems shall be designed optimally at various levels i.e. from the individual sub-systems level to integrator through Control Centre.

815.12.4 OFC transmission system : The system shall comprise optical line terminals**, i**nterface cards and network management. The Backbone Optical Fibre Cable System shall interconnect the sub-centre/integrators and the Control Centre. The Optical Fibre Cable system shall interconnect with the defined optical transmission sources and also if required with associated network devices for signal transmission without any impairment. The backbone communication of Cable system shall be used only to interconnect the sub-centers to the main control centre. This cable shall be terminated only at the sub-centres and main control centre. It shall not be allowed to interface any other sub-systems in the field to this cable or any spare cores in the cable directly or through branching. A separate and independent (auxiliary) Optical Fibre Cable system shall be used for the transmission of video signals, data signals form the equipment locations to the sub-centers where copper cable has limitations for transmission of signals. This would be finalized during approval of detailed design by the successful bidder. All Optical Fibre Cable shall be of TEC (Govt. of India) approved design.

815.12.5 Power supply system : The Power Supply System shall support the requirements of individual sub-systems. The Power Supply System proposed for individual

sub-systems shall take into account the overall availability/reliability requirements. The Power Supply System design shall take into consideration local power availability, temperature and other climatic variations, and easy maintainability.

815.13 Meteorological Data System

815.13.1 General

The Meteorological Data System shall consist of wind sensors for monitoring wind speed and direction, visibility sensors for detection of visibility changes resulting from fog or dust storm, atmospheric sensors to measure air temperature and humidity and road condition sensor to read road surface temperature. The system configuration shall therefore comprise thermocouple/dynamometer, humidity meter , anemometer and visibility meter.

815.13.2 Technical requirements

The Meteorological Data System shall communicate the measurement to the Control Center. It shall be compact, rugged in design and having ease of maintenance and shall be capable of detecting and keeping track of the surface temperature of the Highway surface and initiate appropriate alarms at the Control Centre.

The Met. Sensor shall meet following requirements

Relative Humidity Sensor

Range	:	-100%
Minimum Accuracy	:	± 2% RH
Resolution	;	0.1%
Temperature Range	:	-5ºC to +60ºC
Sensor Mechanism	:	The sensor shall be adequately protected against dust/pollution and shall provide a linear output voltage for 0 – 100% humidity

Air Temperature Sensor

Range	;	-30ºC to +70ºC
Sensing Element	:	should provide a linear output for the entire range of temperature
Resolution	:	0.1% of range
Accuracy	:	±0.3% of range
Visibility Sensor		
Range	:	50 to 1500 m
Wavelength	:	880nm

Sensor Type	:	Infrared sensor, source and detector
Accuracy	:	±15%
Wind Direction Sensor		
Threshold Speed	:	Less than 0.3 m/s
Accuracy	:	Better than ±5%
Damping ratio	:	0.7
Wind Seed Sensor		
Range	:	Up to 79 m/s
Threshold Speed	:	Less than 0.3 m/s
Accuracy	:	±2%
Output Signals	:	Average Wind / Average Gust
Road Condition Sensor		
Temperature Sensor Range	:	-10ºC to +60ºC
Resolution	:	0.1ºC
Accuracy	:	±0.2ºC
Wet/Dry Sensor		
Output	:	ON/OFF

815.13.3 Data acquisition controller :

The Data Acquisition Controller shall meet the following requirements ;

i) Be suitable for all the supplied sensors,

ii) Have appropriate number and type of inputs in order to service all the sensors,

iii) Incorporate an LCD display to allow local monitoring of the data,

iv) Have a memory backup (up to 7 days) to retain data locally in case of communication failure.

815.14 Automatic Traffic Counter cum Classifier

815.14.1 General

This system shall be provided for identifying and recording all types of vehicles on the highway for effective monitoring and data collection at Control Centre. Besides, the system shall be capable of classifying any other vehicle category as per user needs. Vehicle

classification should be user selectable based on length of vehicle and/or detuning of the loop inductivity. The system shall be robust and be capable of operating with minimum maintenance. The system shall interface with the ATMS/ATMS Software for central monitoring. The indicative classification of common vehicles in India, based on wheel base, is as given below.

Type of Vehicle		Probable Range of Wheel Base (mm)
1)	Two Wheelers (Motorised) Scooters, Mopeds, Motor Cycle	0-1350
2)	Three Wheelers (Auto/Tempo)	1400-1800
3)	Four Wheelers Cars, jeeps, vans etc.	1801-2675
4)	Light Motor Vehicles	2690-3400
5)	Trucks/Buses	3401-5600
6)	Multi Axle Vehicles	5000-18000

Vehicle Classification should be user selectably based on length of vehicle and number of axles. The system shall have the capability of accommodating multiple installations through installation of detectors/sensors which can be left permanently in place and connected as required to the recording device when traffic counts are made at that particular location. It shall also be capable of taking inputs from portable sensors and should be modular in design. The system shall have capability of interfacing with the integrators for central monitoring. It shall have suitable interface for transmitting information from ATCC System to the Control Centre.

815.14.2 Technical requirements

815.14.2.1 Sensors : The sensors should be a combination of piezo-electric sensors and inductive loops, enabling counting/classification of up to 4-lane traffic (expandable to atleast 6-lane traffic) with user set time periods.

815.14.2.2 Electronics : Vehicle counting/classification interval shall be programmable from one minute to 1440 minutes (24 hours) and system should accept user programmable recording intervals to count and classify during a 24 hour period. The system should be able to count and classify vehicle by each lane.

815.14.2.3 Data collection : The system shall be capable of sending data to the ATMS/ ATMS Software which shall enable the ATMS/ATMS Software to classify the vehicles, detect average speed per lane, vehicle occupancy and headway as a minimum. Data collection shall be by RS232, RS422 or RS485 interface or IP connection. The system

shall be capable of recording, for later analysis, on an individual vehicle basis, time/date, speed, direction. Number of axles, axle spacing, and site identification.

815.14.2.4 Data storage : The system should be able to record and store vehicle data for a period of at least two weeks with daily traffic voumers of up to 10,000 vehicles.

815.14.2.5 Operating language : English

815.14.2.6 System accuracy : The accuracy of the system in recording speeds and headways/gaps shall as per Table 800-15.

Table 800-15 System Accuracy Requirements

Parameter	Accuracy	Conditions
Average Speed	10 percent	There are at least 25 vehicles in the group, individual vehicle speeds are between 10 kmph and 195 kmph and the vehicles conform to normal highway driving behaviour.
Average Headway	10 percent	There are at least 25 vehicles in the group, individual vehicle speeds are between 10 kmph and 195 kmph, individual vehicle head-ways are between 1 and 10 seconds and the vehicles conform to normal highway driving behaviour.
Flows	5 percent	There are at least 100 vehicles of each category in group and vehicles conform to normal highway driving behaviour.
Occupancy	10 percent	There are at least 25 vehicles in the group, individual vehicle speeds are between 10kmph and 195kmph, individual vehicle headways are between 1 and 10 seconds and the vehicles conform to normal highway driving behaviour.

815.14.2.7 Data retrieval : The system should have the capability of data retrieval, direct data transfer through a serial link to computer, Leased line/GSM/CDMA.

815.14.2.8 Software : Software and manuals to analyze the data from output of vehicle counts, classification speeds and headways shall be provided. Capability of graphic/tabular presentation of analyzed data shall also be offered.

815.14.2.9 Mode of operation : This will be user programmable up to at least 12 speed and 15 vehicle class bins, of vehicles operating in India (user specified). System capability in this regard may be indicated. Counter shall also bin simultaneously in speed, axle and count or any combination of the three.

815.14.2.10 Capability : The system shall have capability of recording vehicle counting and classification, speed, headway at set interval of 1-10 minutes.

815.15. Video Surveillance System

815.15.1 General

The System shall be provided to monitor the movement of vehicles on the highway. System configuration shall comprise video camera, video camera housing, pan and tilt heads, optical transmission units for video and data (if required) and mounting poles at camera locations. The Control centre configuration shall comprise monitors for individual cameras, matrix switcher, multiplexer and digital video recorder with suitable interface for the integrated highway package and optical interface units to the backbone communication system wherever required (where the video and data cannot be transported from camera location to the Sub-centre on co-axial cable). The Video Camera location shall be easily identifiable. The Video Camera shall be of dome type to avoid pilferage, be resistant to vandalism and weather-proof. The mounting and equipment housing shall be able to withstand adverse weather conditions and the Video Camera shall be capable of working satisfactorily under worst weather conditions. The Video Camera and associated units shall be water ingress and dust proof. The Video Camera mounting shall have easy accessibility for maintenance purposes.

815.15.2 Technical requirements

815.15.2.1 The Video Camera shall meet the following minimum technical as requirements :

a)	Image Sensor	¼" CCD with 22 x optical zoom
b)	Active Pixels	752(H)x582(V)
c)	Horizontal Resolution	Minimum 470 lines
d)	Sensitivity	0.02 lux @ 1/1.5 Second shutter speed
e)	Focus	Automatic (with manual override/preset facility)
f)	Signal to Noise	>50 dB
g)	AGC	Automatic with manual override
h)	White Balance	Automatic with manual override
i)	Auto Shutter	Yes
j)	Signal Format	NTSC/PAL

815.15.2.2 The video camera shall have angular travel as below :

Horizontal : 360º continuous pan

Vertical Tilt ; +2º to -92º

The Video Camera shall have speed as below:

Manual Speed

Pan : 1/10º to 80º/second (Variable)

Tilt : 1/10º to 40º/second (Variable)

Preset Speed

Pan : 250º/second

Tilt : 200º/second

815.15.2.3 The dome drive shall have 40 presets with labels and shall have an accuracy of +/-0.25º preset accuracy. It shall have built-in protection against power Line Surge and Lightning and provision for Onscreen-compass and Tilt display, integral, auto sensing multi-protocol receiver/drive and provision for Auto-flip dome rotation. There shall be programmable limit stops for Auto/random/frame scan modes. The Video Camera shall be connected to the control centre/sub-centre through co-axial cable and data cable/optical fibre cable as per the site requirement and shall have remotely selectable operating modes and shall be operated from the Control Centre. The video images from camera shall be transmitted in real time. The video image shall be made available at the control centre without any distortion or loss of information. The video camera system shall have the facility for zone blanking, auto identification of zones when the pan movement of camera is active and infra-red compatibility for night operation.

815.16 Video Incident Detection System

815.16.1 The system shall be an intelligent image detection system using CCTV cameras. The cameras shall have inbuilt intelligence to ascertain when the image has meaningfully deviated from the Standard Image originally recorded. On sensing the incident, the system shall automatically start recording the image at the control centre.

815.16.2 The Incident Detection system shall capable of the following :

a) Measurement of traffic flow speed between 0 and 150 km/hr for up to 6-lanes

b) Detection of vehicles driving in wrong direction

c) Automatic detection of 5 types of traffic flow: normal, dense, delayed, congested, and stop and go

d) Detection of stopped vehicles, within 10 secs and for up to 16 detection zones.

e) Monitor Zone occupancy of the detection area

f) Detection of deceleration

g) Detection of fog/smoke

815.16.3 Alarms for following events:

a) Queue

b) Stop

c) Inverse direction

d) Speed drop

e) Fog/smoke

f) No video signal

g) Error

815.17 Control Centre

815.17.1 General

The Control Centre shall accommodate following equipment and software:

i) Central Computer Server (with integrated ATMS/ATMS Software)

ii) Emergency call management system equipment and software

iii) CCTV Console and other Equipment

iv) Mobile radio operator and configuration equipment and software

v) Video incident detection system console and other equipment

vi) Backbone communication equipment and NMS for the same .

vii) Large Display Board

viii) Printer

ix) Uninterrupted Power Supply with supply system and back up

x) Power supply equipment.

815.17.2 Emergency call management

Emergency Call Management system located at the Control Centre shall carry out the following functions:

i) Attend to incoming calls from ECB's using a PC based console, and navigate the highway section under supervision using graphical representation of the network which shall be displayed on the PC monitor.

ii) Provide audible and visual alert on the screen for any incoming calls from the Emergency call boxes. Colour of the icon representing the Call boxes on the graphical map shall change indicating the states of call box (phone) healthy, call box (phone) faulty, incoming call, conversation in progress and call on hold.

iii) Provide for call waiting signal to the ECB and put the call on queue in case of several calls at the same time.

iv) Create log and record all conversations from and to the Control Centre from the ECBs.

v) Further the system shall automatically check periodically (the interval of which shall be operator selectable) the health of phones and generate an audio visual alarm in case of faults.

vi) The system shall generate a unique call number for each and every call and allow the operator to provide annotation.

vii) There shall be one Emergency Call Manager's terminal easily expandable to more operator stations by connecting more operator terminals.

viii) Holding of any call by the operator.

ix) Terminating any call by the operator.

x) Seamless configuration on addition/deletion of ECBs on the network.

xi) Database generation, display on the monitor and logging of all parameters of call progress.

xii) Recording of communication between the operator and road users.

xiii) Audio visual alarm in case of vandalism.

xiv) Audio visual alert in case of operation by handicapped.

815.17.3 Integrated ATMS software

The ATMS software shall manage the following on a single server platform:

a) Emergency Communication System

b) Variable Message Signs System

c) Meteorological Data System

d) Automatic Traffic Counter cum Classifier System

e) Video Incident Detection System

f) CCTV Surveillance System.

815.17.4 System architecture

815.17.4.1 Hardware for central server

The system shall run on a powerful dual-processor server with RAID facilities to provide continuity of hard disk storage. Storage capacity should be large ;and comfortably sufficient to cater for the demands of a modern traffic management system. The system shall have client-server architecture so that multiple users may access the system simultaneously.

Minimum hardware specification shall be as follows:

a) Server from reputed company

b) Dual Core 2.2 GHz Processor or Higher

c) Hard Disc : 5* 146 (RAID 5 Support)

d) 4Gb RAM or higher

e) Operating system : Industry standard

f) The database : Industry standard

g) Tape drive for backup/archive

h) Facility for remote diagnosis and support.

815.17.4.2 Hardware for work stations/operator console

The workstations shall have the following specifications:

a) Pentium IV 2.0 GHz

b) 512 Mb RAM

c) 80GB ; Hard Drive

d) 19’’ TFT monitor

815.17.4 System software

The System software shall run on industry standard Server platform incorporating either MS Windows or Linux operating system in a client server mode. All the above subsystems shall be displayed and managed by the Supervisor which will show the status of all the above subsystems simultaneously as graphic symbols/icons. The graphic operator interface shall be menu driven for ease of operation. The operator shall be able to configure, set values, commands, perform database operations, reports, archive using these menus. The Integrated ATMS software shall monitor and record online all data from ATCC, Met Sensors, VMS, Traffic control system, CCTV,VIDS and ECBs. It shall be possible to configure the sub-systems as well as add/delete components of the system such as ECB, VMS, MET sensor, ATCC, VIDS, and CCTV in the ATMS software online seamlessly.

The Integrated ATMS Software shall also have following features :

i) The system server shall be configured so as to minimize the risk of data loss in the event of system failure of power loss. It shall support client terminals operating on a LAN, WAN or remote connection. Access to the database and client terminals shall be username and password controlled. Access level shall be determined by the system supervisor and shall range from “read only” to full edit/supervisor rights. The system shall not bypass/violate access rights setup on slave systems. It shall not be possible to send shut down or “Kill” commands form the database management system.

ii) For system monitoring it shall be possible to configure a view only user with access to the map and embedded/linked data only. Such a terminal could be used by police, highway engineers, emergency services, etc. It shall be possible to relay urgent faults/incidents/System alarms (supervisor configurable) to remote operators/staff via an SMS message for any requirements in future.

iii) The system shall have proven and modular Web interfaces. It should be possible to integrate the same if required in future for providing highway information such as CCTV images, traffic flow, journey time, etc., to the general public via internet web pages.

iv) The system shall have proven and modular interfaces to automatic license plate recognition system. It shall be possible to integrate the same in future if required.

815.17.5 System functions

815.17.5.1 Sub-system monitoring and control

The System software shall monitor and control ATMS sub-systems as below :

i) It shall monitor and record online all data from Meteorological Data System installed on the highway. The data shall be updated every five minutes.

ii) It shall monitor and record online all data from the ATCC. The system shall provide the user with the information/display of traffic flow conditions on the MAP. The data shall be updated every one minute.

iii) It shall monitor health of the Emergency telephones on a continuous basis.

iv) It shall monitor and control the variable message signs. The operator shall be able to generate new messages for signs. The system shall react intelligently and automatically to the highway conditions and set up suitable messages on the VMS. It shall also be possible to schedule the pre-defined messages to be displayed on the VMS. The display period shall be operator selectable. The priorities of the messages shall also be operator selectable.

v) The System software shall provide information regarding incidents (VIDS) and store/archive them for future use.

vi) The system shall interface with intelligent traffic control systems for traffic control and monitoring specially at interchanges and access points.

vii) The system shall interface to CCTV system to select cameras for display and control of images.

viii) The system shall process above referred data acquired through above system for decision taking, display information on respective VDU monitors and central Large Display Board.

ix) Provide continuously clear and comprehensive displays and print log of events.

x) Access to historical data files of ATMS.

xi) Execution of operator commands with access code security.

xii) Generation of reports at specified times (operator selectable)

xiii) System timekeeping.

xiv) Connectivity and data transfer to other control centers if required.

815.17.5.2 Graphic User Interface (GUI)

The GUI for the system shall be map based and menu driven. The changes commands/ menu shall be simple to be executed by the operator. There shall be a screen depicting the map of the highway along with other equipment installed on the route. The highway map shall be capable of displaying an overview level showing the whole area covered by the system. It shall then be possible with no loss of definition, to zoom to a detailed map. It shall be possible to display both static and dynamic data on the Map. Two level of mapping shall be supported as a minimum:

1) Highway Overview.
2) Highway section wise detailed view.

Icons shall be placed on the map to identify different equipment types. Both shall be automatically tagged with grid reference data to allow them to appear in the correct relative positions at both levels of map. Positioning the mouse pointer over an icon or poly-line shall display the corresponding equipment status information.

For poly-lines representing route data, the user shall be able to configure a number of thresholds for the different data types available. An example would be congestion for links where up to X% percentage thresholds can be defined. Each threshold shall be represented by a distinct colour or changed shapes. The map shall use this scheme to display the poly-lines based on comparisons with the current real-time data.

The user shall have the ability to configure the map view to display the data layers of choice, for example to show Met Sensor only or ATCC together with current incidents.

It shall be possible for the operator to place icons or “active” symbols on the map to represent

a) Access control/ramp metering system
b) Traffic control system
c) Variable Message signs
d) CCTV cameras
e) Incidents such as Accident, Roadworks, Event, Diversion, Breakdown and Road closure
f) Strategy
g) Weather station data
h) Flow, speed classification information
i) User defined fields

Icons will be either active or non-active. Active icons will link to the associated system and show their current status change of state (colour or flash) and by displaying detailed information triggered user action.

815.17.6 Date base management

The database used by the ATMS software shall be an industry standard database like ORACLE, SQL, dbase etc. The system shall have facility to perform certain selected database operations only by authorized users.

815.17.6.1 Data presentation and storage

The presentation of data shall reflect the use of the system as a real time tool for the operator to monitor and control the highway. It shall be possible to present current data (day) in comparison with profile data or date comparison (same day last year). It shall be possible to create predictive traffic data and trends. The data shall be stored in the system in a format to present weekly and monthly average for congestion and summary flow for weeks and months. The system shall store at least 12 months of data. Older data may be archived. However, the system shall provide tools for the retrieval, manipulation and presentation of data. Data store shall be clearly marked with an indicator to show day or period type e.g. normal, holiday, weekly off; by reference to the system calendar. It shall be possible to export data to an external system for further analysis. Transfer shall be available in .xls , csv or any standard formats. It shall be possible to display data or combinations of data in graphical manner and to print graphs, e.g., Graphs of current, profile, historic, and combinations for

a) Flow
b) Occupancy
c) Congestion

815.17.6.2 Archive and Restore

This facility shall allow the archiving of the database to a tape/External HD/DVD . The data archived shall then be deleted from the database. Data may only be archived when it is more than two years old. Only one archive request may be outstanding at a time. Once archived, part or all of the data may be restored by copying from the tape back onto the system, where it remains for 30 days. Only one restore request may be outstanding at a time.

It shall be possible to define a series of notification levels which will raise an alarm when the disk space reaches a specified limit. This is used to alert an operator to the need to archive data.

815.17.6.3 Database back-up

The system management procedures for producing daily and weekly back-ups shall not need any operator intervention.

815.17.6.4 Reports

The system shall have detailed reports for:

a) Status reports for the sub-systems (alarms, faults etc.)

b) Detailed traffic reports-speed, count, occupancy etc.

c) Detailed weather report for all variables from weather sensor

d) Detailed report of emergency call.

815.17.6.5 Timetable and calendar

The system shall have a time table facility. The timetable shall allow commands by day of the week, time of day, day type. The system calendar shall allow days to be marked as normal, holiday, weekly off, etc.

815.17.6.6 System log

The system shall retain a log of all events, alarms, timetable actions, and operator actions(together with operator username). In addition to system generated events the operators shall have facilities to enter events or incidents into the log. It shall be possible to search the log by time/date, event type, operator user name, strategy, location.

The log facility shall provide the means to:

a) Record all important events that occur in the operation of the integrated highway management system, both manual and automatic View and manage the status of alarm events,

b) Collect and collate incident information from both manual and automatic sources,

c) Allow the user to record routine operational messages,

d) View all changes and actions taken on the ATMS,

e) Record and view useful contact names and other details.

815.17.6.7 Asset management

a) The system shall incorporate a facility to store records of assets for ATMS.

b) The asset register shall store data relating to location, type, and number of equipments as well as electricity ratings.

815.17.6.8 User management

This facility shall provide the means to make user access to ATMS secure. Only the system administrator(s) shall have access to this facility and will set up details for other users. Each user shall have a username that needs to be configured so that it matches a PC log-in. Hence logging on to the PC will automatically mean that access to ATMS is available for the chosen users. Each user can also be configured to have access to none, some or all of the ATMS facilities.

815.17.7 Operator interface and control

815.17.7.1 Fault and alarm management

Fault and Alarm Monitoring (FAM) for ATMS shall have following features :

a) The FAM system shall be provided with the capabilities to monitor system alarm status on a real-time basis.

b) The FAM system shall have the ability to store alarms in the database for future enquiries, and to access the fault alarm history database for retrieval of alarm data in the alarm history memory.

c) All ATMS controlled equipment as well as VMS display boards shall be provided with fault monitoring and reporting to the FAM system.

815.17.7.2 Alarm handling

a) The following alarm conditions shall be provided to the FAM system as a minimum:

i) Loss of communication link

ii) Loss of the entire ATMS facilities at a location

iii) Loss of interface link with the ECB

iv) Alarm from MET Sensor-Air Temperature, Visibility, Humidity, Road Surface temperature, Road Surface wet/dry, Wind Speed, wind direction etc.

v) VMS Faults e.g Communication Fault, LED Fault, Data parity fault, Power supply fault, Protocol polling fault to I/O Device, etc.

vi) ATCC faults e.g. Sensor fault, communication link failure etc.

vii) CCTV faults

viii) Traffic control system faults-Lamp LED Fault, Sensor fault, communication link failure, etc.

ix) Power supply unit failure

x) Automatic Message priority conflict.

b) All failure alarms shall be stamped with time and date.

c) All failure alarms shall remain on the active alarm display list until they have been acknowledged by the operator on the FAM system via the management workstation.

d) All alarms removed from the active alarm display list shall automatically be inserted into the alarm history database when they occur.

e) The alarm history database shall be provided with sufficient storage capacity to store the anticipated alarms for a period of at least four weeks without carrying out any housekeeping function.

815.17.7.3 Alarm displays

a) Alarms shall be displayed on the workstation via a detailed full screen alarm browser application.

b) The alarm Display shall provide as a minimum the following general capabilities and characteristics for the ABA for alarm display list and alarm history:

i) A colour coding scheme indicating the alarm severity according to the alarm classifications.

ii) The display of the alarms with their associated time stamps.

iii) Scrolling capabilities to enable the operator to view more alarms that can be displayed on one single screen.

iv) The facilities to acknowledge alarms.

v) The facilities to clear alarms from the display.

815.17.7.4 Fault diagnostics

The fault diagnostics system shall perform the following diagnostics features as a minimum.

i) Detect the alarm conditions as listed in Clause 815.17.7.2.

ii) All fault status information and associated equipment test results shall be presented to the workstation immediately after the alarms are triggered.

815.17.7.5. Failure modes

When power is restored following a power failure to the system, the system shall perform all necessary self-testing processes and then resume functioning fully in the same configuration as before the shutdown. This shall be completed automatically within 5 minutes of power restoration.

815.17.8 Back bone communication system

The backbone communication system shall connect the sub-centers with the Control Centre. The auxiliary Optical Fibre communication system shall provide connectivity for peripheral systems like ATCC, CCTV, mobile radio, emergency call management system, VIDS, Traffic Control System, Mobile Radio and LAN interface for Tolling Systems to the Control Centre. There shall be a node for the backbone communication system at every sub-centre and the Control Centre. The network management system (NMS) shall be located at main Control Centre. It shall however be possible to connect the NMS at any sub-center location which houses a communication node. The NMS shall be installed on a PC.

815.17.9 Large display board

815.17.9.1 Functions

a) The device shall be used for monitoring the traffic through CCTV/ VIDS to display the ATMS Graphical User Interface (GUI). The large display board shall be displayed on the wall of the Control Centre. The Application software shall consist of a built-in module for display board.

b) It shall be possible to create customized data acquisition screen and drag icons by simple click of the mouse.

c) It shall be possible to create backgrounds using scanned photographs, maps, one-line diagrams, engineering drawings, etc, using popular graphic or engineering applications.

d) It shall be possible to create new process diagrams that represent various sections of the highway at different levels of levels of details using the package.

815.17.9.2 Equipment

The Large Display Board shall be highly reliable for installation and round the clock operation in the Control Centre. The Display Board shall be driven by the Central Computer using

the main console. The design of the Display Board system shall be modular and expandable. The Display Board shall use high gain trans-reflective LCDs for ambient indoors. The Board shall meet the following specifications:

i)	Overall board size	Length minimum 3000 mm Height minimum 1200 mm
ii)	Display	Graphic
iii)	Contrast Ratio:	Minimum 1000:1
iv)	Housing	Structure coated housing with IP54 Protection casing against dust, sprayed water
vii)	Interface Standard	RS 422, RS 485 (Ethernet compatible)
viii)	Special Features	Automatic diagnostics and failure reporting

815.17.10 Uninterrupted power supply

815.17.10.1 Functions

The uninterrupted power supply shall be installed at the Control Centre for providing clean uninterrupted power supply to all the operational Equipment at the centre. The uninterrupted power supply shall be capable of providing full load for the operational equipment for a minimum period of 60 minutes. The Control Centre shall be powered from 230V AC from the State Electricity Board (SEB) supply. Any loss of AC power to the Control Centre from the SEB shall not cause loss of any data on the computers or any resetting of system parameters. The following requirements will be met:

Features

Rating	To meet the load requirement
Input Voltage	230 V AC (+10% to -15%)
Input Frequency	50 HZ ± 10%
Inverter Type	High frequency switching sinusoidal multiple Pulse
Output Voltage	230 V
Output Frequency	Free running 50 Hz ± 0.1% Tracking bypass ± 2%
Output Voltage Waveform	Sinusoidal
Output Voltage Regulation	Better than ± 1% for simultaneous variation of no. to full load and input Voltage to any extremes. ±

Total harmonic distortion	<5%
Inverter efficiency	>87%
Transmit Response	for 100% step load Dip-Typical 5% max. <8% Peak-Typical 5% max. <8% Recovery to normal up to 60 msec. i.e. 3 cycles.
Overload capacity	125% for 10 msec. 800% on static bypass for 10 msec.
Audible indication	<55 dBA at 1 meter distance for i) Mains OK ii) Inverter OK iii) Overload iv) On battery v) Low battery vi) Inverter trip

Four extra LED indications shall be available with automatic bi-directional static swith for

i) By pass OK

ii) Load on inverter

iii) Load on By Pass

iv) By Pass frequency out of range

v) Metering for voltage, frequency and current

vi) Battery capacity required for minimum 1-hour back up at full load.

815.18 Warranty : The Contractor/Supplier of the Advanced Traffic Management Systems (ATMS) shall furnish the Warranty/Guarantee for successful commissioning and operation of ATMS for a minimum period of 5 years. He shall also furnish the certificate that there is no proprietary item and that the Systems shall be interoperable. All components and equipments shall be tested for commissioning. The documents with regard to design, technical details, installation details, testing and commissioning, details of fault diagnostics, operation and maintenance manuals and reports shall be submitted to the Engineer by the Contractor/Supplier.

815.19 Payment : The payment shall be made for design, configuration, installation and commissioning the ATMS, as complete job on the identified stretch of highway, as per directions of the Engineer.

1000

Materials for Structures

1001 GENERAL

Materials to be used in the work shall conform to the specifications mentioned on the drawings, the requirements laid down in this section and specifications for relevant items of work covered under these specifications.

If any material, not covered in these specifications, is required to be used in the work, it shall conform to relevant Indian Standards, if there are any, or to the requirements specified by the Engineer.

1002 SOURCES OF MATERIAL

The Contractor shall identify the sources of materials like coarse aggregate and sand and notify the Engineer regarding the proposed sources prior to delivery. .

Samples of materials from the source shall be tested in the presence of Engineer's representative for conformity to Specifications. It shall also be ensured that the variation in test results of different samples is within acceptable limits. If the product from the approved source proves unacceptable at any time the contractor at his own cost shall identify new sources from where materials conforming to Specifications are available.

For manufactured items like cement, steel reinforcement, pre-stressing strands, the contractor shall intimate the Engineer details of the source (plant where the material is manufactured), testing facilities available with the manufacturer and arrangements for transport and storage of material at site. If directed by the Engineer, the contractor shall furnish samples and test results of recently manufactured material. The Engineer, at his discretion, in case of doubt may require the contractor to test the materials in an independent laboratory approved by the Engineer and furnish test certificates. The cost of these tests shall be borne by the contractor. The sampling and test procedures shall be as laid down in Indian Standards or where these are not available as per the directions of the engineer. Materials, only from the sources approved by the Engineer, shall be brought to the site. If the material from the approved sources proves unacceptable at any time, the contractor shall provide new sources of acceptable materials conforming to Specifications at his own expense.

For proprietary items like bearings, expansion joins, refer Clause 115.1 refers

1003 BRICKS

Burnt clay bricks shall conform to the requirements of IS:1077, except that the minimum compressive strength when tested flat shall not be less than 8.4 MPa for individual bricks and 10.5 MPa for average of 5 specimens. They shall be free from cracks and flaws and nodules of free lime. The brick shall have smooth rectangular faces with sharp corners

and emit a clear ringing sound when struck. The size may be according to local practice with a tolerance of ± 5 per cent.

1004 STONES

Stones shall be of the type specified. It shall be hard, sound, free from cracks, decay and weathering and shall be freshly quarried from an approved quarry. Stone with round surface shall not be used.

The stones, when immersed in water for 24 hours, shall not absorb water by more than 5 per cent of their dry weight when tested in accordance with IS:1124.

The length of stones shall not exceed 3 times its height nor shall they be less than twice its height plus one joint. No stone shall be less in width than the height and width on the base shall not be greater than three-fourth of the thickness of the wall nor less than 150 mm.

1005 CAST IRON

Cast iron shall conform to IS:210. The grade number of the material shall not be less than 14.

1006 CEMENT

Cement to be used in the works shall be any of the following types with the prior approval of the Engineer.

a) Ordinary Portland Cement, 33 Grade, conforming to IS: 269.

b) Ordinary Portland Cement, 43 Grade, conforming to IS: 8112.

c) Ordinary Portland Cement, 53 Grade, conforming to IS: 12269.

d) Sulphate Resistant Portland Cement, conforming to IS: 12330.

e) Portland Pozzolana Cement IS: 1489-Part-I & Part -II

f) Portland Blast Furnace Slag Cement IS: 455

g) Rapid Hardening Portland Cement, conforming to IS: 8041.

h) Low heat Portland Cement IS: 12600

Cement conforming to IS: 269 shall be used only after ensuring that the minimum required design strength can be achieved without exceeding the maximum permissible cement content of 540 kg/cu.m. of concrete.

Cement conforming to IS: 8112 and IS: 12269 may be used provided the minimum cement content mentioned elsewhere from durability considerations is not reduced. From strength considerations, these cements shall be used with a certain caution as high early strengths of cement in the 1 to 28-day range can be achieved by finer grinding and higher constituent ratio of C3S/C2S, where C3S is Tricalcium Silicate and C2S is Dicalcium Silicate. In such cements, the further growth of strength beyond say 4 weeks may be much lower than that traditionally expected. Therefore, further strength tests shall be carried out for 56 and 90 days to fine tune the mix design from strength considerations.

Cement conforming to IS: 12330 shall be used when sodium sulphate and magnesium sulphate are present in large enough concentration to be aggressive to concrete. The recommended threshold values as per IS:456 are sulphate concentration in excess of 0.2 per cent in soil sub-strata or 300 ppm (0.03 per cent) in ground water level. Cement conforming to IS: 12330 shall be carefully selected from strength considerations to ensure that the minimum required design strength can be achieved without exceeding the maximum permissible cement content of 450 kg/cu.m. of concrete.

Cement conforming to IS: 8041 shall be used only for precast concrete products after specific approval of the Engineer.

Total chloride content in cement shall in no case exceed 0.05 per cent by mass of cement. Also, total sulphur content calculated as sulphuric anhydride (SO3) shall in no case exceed 2.5 per cent and 3.0 per cent when tri-calcium aluminate per cent by mass is upto 5 or greater than 5 respectively.

Manufacturers test certificate shall be submitted to the Engineer by the contractor for every consignment of cement. The certificate shall cover all the tests for chemical requirements, physical requirements and chloride content as per relevant codes as applicable.

Independent tests of samples drawn from the consignment shall be carried out at the site laboratory or in an independent laboratory approved by the Engineer, immediately after delivery. The following properties shall be tested:

i) Compressive strength.
ii) Setting time.

The cost of the tests shall be borne by the contractor. In case the cement is stored beyond 90 days from the date of delivery at site, the following tests shall be carried out again at the site laboratory before the cement is used:

i) Compressive strength.;
ii) Setting time.

Lot size for independent testing of cement at site shall be the quantity received at site on any day, subject to a maximum of 500 tonnes.

1007 COARSE AGGREGATES

For plain and reinforced cement concrete (PCC and RCC) or prestressed concrete (PSC) works, coarse aggregate shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone, crushed gravel, natural gravel or a suitable combination thereof or other approved inert material. They shall not consist pieces of disintegrated stones, soft, flaky, elongated particles, salt, alkali, vegetable matter or other deleterious materials in such quantities as to reduce the strength and durability of the concrete, or to attack the steel reinforcement. Coarse aggregate having positive alkali silica reaction shall not be used. All coarse aggregates shall conform to IS: 383 and tests for conformity shall be carried out as per IS: 2386, Parts I to VIII.

The contractor shall submit for the approval of the Engineer, the entire information indicated in Appendix A of IS: 383.

Maximum nominal size of coarse aggregate for various structural components in PCC, RCC or PSC, shall conform to Section 1700.

The maximum value for flakiness index for coarse aggregate shall not exceed 35 per cent. The coarse aggregate shall satisfy the following requirements of grading :

TABLE 1000-1 REQUIREMENTS OF COARSE AGGREGATE

IS Sieve Size	Per cent by Weight Passing the Sieve		
	40 mm	20 mm	12.5 mm
63 mm	100	—	—
40 mm	95-100	100	—
20 mm	30-70	95-100	100
12.5 mm	—	—	90-100
10 mm	10-35	25-55	40-85
4.75 mm	0-5	0-10	0-10

1008 SAND/FINE AGGREGATES

For masonry work, sand shall conform to the requirements of IS:2116.

For plain and reinforced cement concrete (PCC and RCC) or prestressed concrete (PSC) works, fine aggregate shall consist of clean, hard, strong and durable pieces of crushed stone, crushed gravel, or a suitable combination of natural sand, crushed stone or gravel.

They shall not contain dust, lumps, soft or flaky, materials, mica or other deleterious materials in such quantities as to reduce the strength and durability of the concrete, or to attack the embedded steel. Motorised sand washing machines should be used to remove impurities from sand. Fine aggregate having positive alkali-silica reaction shall not be used. All fine aggregates shall conform to IS:383 and tests for conformity shall be carried out as per IS:2386, (Parts I to VIII). The Contractor shall submit to the Engineer the entire information indicated in Appendix A of IS:383. The fineness modulus of fine aggregate shall neither be less than 2.0 nor greater than 3.5.

Sand/fine aggregate for structural concrete shall conform to the following grading requirements:

TABLE 1000-2.

IS Sieve Size	Per cent by Weight Passing the Sieve		
	Zone I	Zone II	Zone III
10 mm	100	100	100
4.75 mm	90-100	90-100	90-100
2.36 mm	60-95	75-100	85-100
1.18 mm	30-70	55-90	75-100
600 micron	15-34	35-59	60-79
300 micron	5-20	8-30	12-40
150 micron	0-10	0-10	0-10

1009 STEEL

1009.1 Cast Steel

The use of cast steel shall be limited to bearings and other similar parts. Steel for castings shall conform to Grade 280-520N of IS:1030. In case where subsequent welding is unavoidable in the relevant cast steel components, the letter N at the end of the grade designation of the steel casting shall be replaced by letter W. 0.3 per cent to 0.5 per cent copper may be added to increase the corrosion resistance properties.

1009.2 Steel for Prestressing

The prestressing steel shall conform to either of the following :

a) Plain hard drawn steel wire conforming to IS:1785 (Part I) and IS:1785 (Part II)

b) Cold drawn indented wire conforming to IS:6003

c) High tensile steel bar conforming to IS:2090

d) Uncoated stress relieved strands conforming to IS:6006

e) Uncoated stress relieved low relaxation steel conforming to IS: 14268

Data in respect of modulus of elasticity, relaxation loss at 1000 hours, minimum ultimate* tensile strength, stress strain curve etc. shall be obtained from manufacturer. Pre-stressing steel shall be subjected to acceptance tests prior to actual use on the works. Guidance in this regard be taken from BS:4447. The modulus of elasticity value, as per acceptance tests shall conform to the design value which shall be within a rnage not more than 5% between the maximum and minimum.

1009.3 Reinforcement / Untensioned Steel

For plain and reinforced cement concrete (PCC and RCC) or prestressed concrete (PSC) works, the reinforcement / untensioned steel as the case may be shall consist of the following grades of reinforcing bars.

TABLE 1000-3

Grade Designation	Bar Type conforming to governing IS Specifications	Characteristic Strength fy MPa	Elastic Modulus GP
S 240	IS:432 Part I Mild Steel	240	200
S 415	IS:1786 High Yield Strength Deformed Bards (HYSD)	240	200
Fe 500	IS: 1786 Deformed bar	500	200
Fe 550D	IS: 1786 Deformed bar	550	200

Note: i) Wire fabrics conforming to IS: 1566 and TMT bars conforming to IS: 1786 can also be used.

ii) Other grades of bars conforming to IS:432 and IS:1786 shall not be permitted.

All steel shall be procured from main producers, SAIL (including IISCO,ASP,SALEM,VISL), Tata Steel, Vizag Steel Plant (RINL) and Major producers ESSAR, Ispat & JSW Steel Ltd. In case of procurement of steel from units other than the main/major producer specific approval of the Engineer is required. For which credential verification shall be undertaken regarding the fact that these units are conversion agent of main/major producer for steel bars with clean track record of performance. The procurement of steel from conversion agent shall satisfy the following minimum requirement;

a) A certificate from main /major producer that the billets are supplied by them and have been tested as per IS 2830 and are of prime quality.

b) No re-rolled steel from induction furnace route or defective billets from main/major producer have been used by the conversion agent for production of bars.

c) Certificate from the conversion agent that he had used the billets supplied by main/major producer as per a) above with production of invoice in support in support of the same.

d) Certificate from the conversion agent that manufacturing had been done by the conversion agent as per main/major producer's standard and quality control.

e) Certificate regarding continuity of the BIS license and agreement with the Main/Major producer being its authorized conversion agent during the currency of supply contract.

Only new steel shall be delivered to the site. Every bar shall be inspected before assembling on the work and defective, brittle or burnt bar shall be discarded. Cracked ends of bars shall be discarded.

The client/employer may exercise occasional checks of material conformity with the test certificates of Main/Major producers including supply from conversion agent through chemical analysis by any third party, in case of doubt regarding the quality of steel supplied

Fusion-bonded epoxy coated reinforcing bars shall meet the requirements of IS:13620. Additional requirements for the use of such reinforcement bars have been given below:

a) Patch up materials shall be procured in sealed containers with certificates from the agency who has supplied the fusion bonded epoxy bars.

b) PVC coated G.I. binding wires of 18G shall only be used in conjunction with fusion bonded epoxy bars.

c) Chairs for supporting the reinforcement shall also be of fusion bonded epoxy coated bars.

d) The cut ends and damaged portions shall be touched up with repair patch up material.

e) The bars shall be cut by saw-cutting rather than flame cutting.

f) While bending the bars, the pins of work benches shall be provided with PVC or plastic sleeves.

g) The coated steel shall not be directly exposed to sun rays or rains and shall be protected with opaque polyethyelene sheets or such other approved materials.

h) While concreting, the workmen or trolley shall not directly move on coated bars but can move on wooden planks placed on the bars.

When specified in the contract, protective coating prescribed to steel shall be provided as per the provisions of the specifications. CECRI coating shall conform to the specifications given in *Appendix 1000/1.* The CECRI coating process shall be allowed to be implemented at the site of works provided a representative of the Institute is present throughout the duration of the coating process who shall certify that the materials and workmanship are in accordance with prescribed specifications developed by the Institute.

When specified in the contract, Zinc Rich Cold galvanized coated reinforcement conforming to specifications given in Appendix 1000/2 shall be provided in protection against corrosion. This type of coating work on the principle of composite actions of sacrificial and barrier protection of corrosion process. Additional requirements for the use of such reinforcement bars are given below:

a) While bending the bars, the pins of work benches shall be provided with PVC or plastic sleeves.

b) The bundling of the coated steel bars shall be done so that no rubbing on surface takes place during transportation.

c) Storage and staging of the coated bars shall be so as to avoid direct cont5ract with the soils.

d) For longer storage the coated steel shall not be exposed to sun rays or rains and shall be protected with opaque polythelene sheets.

1009.4 Grey Iron Castings

Grey Iron castings to be used for bearings shall have the following minimum properties:

i)	Minimum ultimate tensile strength	370 MPa
ii)	Modulus of Elasticity	147000 Mpa
iii)	Brinell Hardness	230 MPa
iv)	Shear Strength	370 MPa
v)	Compressive Strength	1370 MPa

The testing shall be as specified in IS: 210.

1009.5 Steel Forgings

Forged steel pins shall comply with clause 3, 3A or 4 of IS: 1875 and steel forgings shall comply with clause 3, 3A or 4 of IS: 2004. Raw materials of the forging will be taken as per IS: 1875 with minimum reduction ratio of 1.8:1. Alternatively, if forging is made from ingot, a minimum reduction ratio between the ingot and forging will be 4:1. Forging shall be normalized.

1009.6 Structural Steel

Unless otherwise permitted herein, all structural steel shall before fabrication comply with the requirements of the following Indian Standards:

IS: 226	:	Structural Steel (Standard Quality)
IS: 961	:	Structural Steel (High Tensile)
IS: 2062	:	Weldable Structural Steel
IS: 8500	:	Weldable Structural Steel (medium & high strength qualities)
IS: 1148	:	Hot rolled rivet bars (upto 40mm dia) for structural purposes
IS: 1149	:	High tensile river bars for structural purposes
IS: 1161	:	Steel tubes for structural purposes
IS: 4923	:	Hollow Steel sections for structural use
IS: 11587	:	Structural weather resistant steel
IS: 808	:	Specifications for Rolled Steel Beam, Channel and Angle Sections
IS: 1239	:	Mild Steel Tubes
IS: 1730	:	Dimension for Steel Plate, sheet and strip for structural and general Engineering purposes.
IS: 1731	:	Dimension for Steel flats for structural and general engineering purposes
IS: 1732	:	Dimension for round and square steel bars for structural and general engineering purposes.
IS: 1852	:	Rolling and cutting tolerances for hot rolled steel products

The use of structural steel not covered by the above standards may be permitted with the specific approval of the authority. Refer to Section 1900 for further details.

1009.7 Stainless Steel

Stainless steel shall be austenitic chromium-nickel steel, possessing rust, acid and heat resistant properties conforming to IS: 6603 and IS: 6911. Mechanical properties/grade for such stainless steel shall be as specified by the accepting authority, but in no case be inferior to mild steel. Generally, stainless steel is available as per AISI grades. AISI 304

which is equivalent to grade 04Cr18Ni110 of IS: 6911 satisfies the requirements for mechanical properties of structural steel. Other grades of stainless steel for specific purposes may be provided as per specific requirements. For application in adverse/ corrosive environment, stainless steel shall conform to AISI 316L or 02G17 Ni Mo2 of IS: 6911.

1010 WATER

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

In case of doubt regarding development of strength, the suitability of water for making concrete shall be ascertained by the compressive sstrength and initial setting time tests specified in 302.4.1.2 and 302.4.1.3.

The sample of water taken for testing shall represent the water proposed to be used for concreting, due account being paid to seasonal variation. The sample shall not received any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previsously rinsed out with similar water.

Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90 per cent of the average strength of three similar concrete cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with the requirement of IS:516.

The initial setting time of test block made with the appropriate cement and the water proposed to be used shall not be less than 30 minutes and shall not be more than 30 minutes from the initial setting time of control test block prepared with the same cement and distilled water. The test blocks shall be prepared and tested in accordance with the requirements of IS:4031 (Part 5).

pH value of water shall be less than 6. Potable water is generally considered satisfactory for mixing concrete. Mixing and curing with sea water shall not be permitted. As a guide, the following concentrations represent the maximum permissible values:

a) To neutralize 200 ml sample of water, using phenolphthalein as an indicator, it should not require more than 2 ml of 0.1 normal NaOh.

b) To neutralize 200 ml sample of water, using methyl orange as in indicator, it should not require more than 10 ml of 0.1 normal HCL.

c) The permissible limits for solids shall be as follows when tested in accordance with IS: 3025: Permissible Limits (mix)

Organic	200 mg/lit
Inorganic	3000 mg/lig
Sulphates (SO3)	400 mg/lit
Chlorides (Cl)	2000 mg/lit *
Suspended matter	2000 mg/lit

All samples of water (including potable water) shall be tested and suitable measures taken where necessary to ensure conformity of the water to the requirements stated herein.

1011 TIMBER

The timber used for structural purposes shall conform to IS:883.

1012 CONCRETE ADMIXTURES

1012.1 General

Admixtures are materials added to the concrete before or during mixing with a view to modify one or more of the properties of concrete in the plastic or hardened state.

Concrete admixtures are proprietary items of manufacture and shall be obtained only from established manufacturers with proven track record, quality assurance and full fledged laboratory facilities for the manufacture and testing of concrete.

The contractor shall provide the following information concerning each admixture after obtaining the same from the manufacturer:

a) Normal dosage and detrimental effects, if any, of under dosage and over dosage.

b) The chemical names of the main ingredients in the admixtures.

c) The chloride content, if any, expressed as a percentage by the weight of the admixture.

d) Values of dry material content, ash content and relative density of the admixture which can be used for Uniformity Tests.

e) Whether or not the admixture leads to the entertainment of air when used as per the manufacturer's recommended dosage, and if so to what extent.

f) Where two or more admixtures are proposed to be used in any one mix, confirmation as to their compatibility.

g) There would be no increase in risk of corrosion of the reinforcement or other embedments as a result of using the admixture.

1012.2 Physical and Chemical Requirements

Admixtures shall conform to the requirements of IS:9103. In addition, the following conditions shall be satisfied.

a) "Plasticisers" and "Super-Plasticisers" shall meet the requirements indicated for "Water reducing Admixture".

b) Except where resistance to freezing and thawing and to disruptive action of deicing salts is necessary, the air content of freshly mixed concrete in accordance with the pressure method given in IS:1199 shall not be more than 2 per cent higher than that of the corresponding control mix and in any case not more than 3 per cent of the test mix.

c) The chloride content of the admixtures shall not exceed 0.2 per cent when tested in accordance with IS:6925. In addition, the maximum permissible limit of chloride content of all the constituents as indicated in Section 1700 shall also be observed.

d) Uniformity tests on the admixtures are essential to compare qualitatively the composition of different samples taken from batch to batch or from the same batch at different times.

The tests that shall be performed along with permissible variations in the same are indicated below:

- Dry Material Content : to be within 3 per cent and 5 per cent of liquid and solid
- Ash content : to be within 1 per cent of the value stated by the manufacturer.

Relative Density (for liquid admixtures) : to be within 2 per cent of the value stated by the manufacturer.

e) All tests relating to the concretes admixtures shall be conducted periodically at an independent laboratory and compared with the data given by the manufacturer.

1013 REINFORCED CONCRETE PIPES

Reinforced concrete pipes for highway structures shall be of NP4 type conforming to the requirements of IS:458. Prestress concrete pipes (NP 4) conforming to IS 784 can also be used depending upon the requirement.

1014 STORAGE OF MATERIALS

1014.1 General

All materials may be stored at proper places so as to prevent their deterioration or intrusion by foreign matter and to ensure their satisfactory quality and fitness for the work. The storage space must also permit easy inspection, removal and restorage of the materials. All such materials even though stored in approved godowns/places, must be subjected to acceptance test prior to their immediate use.

1014.2 Brick

Bricks shall not be dumped at site. They shall be stacked in regular tiers as they are unloaded, to minimize breakage and defacement. The supply of bricks shall be available at site at any time. Bricks selected for use in different situations shall be stacked separately.

1014.3 Aggregates

Aggregate stockpiles may be made on ground that is denuded of vegetation, is hard and well drained. If necessary, the ground shall be covered with 50 mm plank.

Coarse aggregates, unless otherwise agreed by the Engineer in writing, shall be delivered to the site in separate sizes (2 sizes when nominal size is 25 mm or less and 3 sizes when the nominal size is 32 mm or more). Aggregates placed directly on the ground shall not be removed from the stockpile within 30 cm. of the ground until the final cleaning up of the work, and then only the clean aggregate will be permitted to be used.

1014.4 Cement

Cement shall be transported, handled and stored on the site in such a manner as to avoid deterioration or contamination. Cement shall be stored above ground level in perfectly dry and water-tight sheds and shall be stacked not more than eight bags high. Wherever bulk storage containers are used their capacity should be sufficient to cater to the requirement at site and should be cleaned at least once every 3 to 4 months.

Each consignment shall be stored separately so that it may be readily identified and inspected and cement shall be used in the sequence in which it is delivered at site. Any consignment or part of a consignment of cement which had deteriorated in any way, during storage, shall not be used in the works and shall be removed from the site by the Contractor without charge to the Employer.

The Contractor shall prepare and maintain proper records on site in respect of delivery, handling, storage and use of cement and these records shall be available for inspection by the Engineer at all times.

The Contractor shall make a monthly return to the Engineer on the date corresponding to the interim certificate date, showing the quantities of cement received and issued during the month and in stock at the end of the month.

1014.5 Reinforcement / Untensioned Steel

The reinforcement bars, when delivered on the job, shall be stored above the surface of the ground upon platforms, skids or other supports, and shall be protected from mechanical injury and from deterioration by exposure.

1014.6 Prestressing Materials

All prestresssing steel, sheathing, anchorages and sleeves or coupling must be protected during transportation, handling and storage. The prestressing steel, sheathing and other accessories must be stored under cover from rain or damp ground and protected from the ambient atmosphere if it is likely to be aggressive. Storage at site must be kept to the absolute minimum.

a) **Tendon** : Wire, strand and bar from which tendons are to be fabricated shall be stored about 300mm above the ground in a suitably covered and closed space so as to avoid direct climatic influences and to protect them from splashes from any other materials and from the cutting operation of an oxy-acetylene torch or are welding process in the vicinity. Under no circumstances, tendon material shall be subjected to any welding operation or on site beat treatment or metallic coating such as galvanizing. Storage facilities or on site heat treatment or matalic coating such as galvanizing. Storage facilities and the procedures for transporting material into or out of store, shall be such that the material does not become kinked or notched. Wire or strand shall be stored in large diameter coils which enable the tendons to be laid out straight. As a guide, for wires above 5mm dia, coils of about 3m dia without breaks or joints shall be obtained from manufacturer and stored. Protective wrapping for tendons shall be chemically neutral. All prestressing steel must be provided with temporary protection during storage.

b) **Anchorage Components** : The handling and storing procedures shall maintain the anchorage components in a condition in which they can subsequently perform their function to an adequate degree. Components shall be handled and stored so that mechanical damage and detrimental corrosion are prevented. The corrosion of the gripping and securing system shall be prevented. The use of correctly formulated oils and greases or of other corrosion preventing material

shall be guaranteed by the producer to be non-aggressive and non-degrading.

Prestressing steel shall be stored in a closed store having single door with double locking arrangements and no windows. Also the air inside the store shall be kept dry as far as possible by using various means to the satisfaction of the Engineer. Also instrument measuring the air humidity shall be installed inside the store. This is with a view to eliminating the possibility of initial rusting of prestressing steel during storage. The prestressing steel shall be coated with water solvable-grease. The prestressing steel should be absolutely clean and without any signs of rust.

All prestressing steel shall be stored at least 30 cm above ground level and it shall be invariably wrapped by protective cover of tar paper or polythene or any other approved material.

The Contractor should see that prestressing steel shall be used within 3 months of its manufacture. He should chalk out his programme in this respect precisely, so as to avoid initial corrosion before placing in position.

1014.7 Water

Water shall be stored in containers/tanks covered at top and cleared at regular intervals in order to prevent intrusion by foreign matter or growth of organic matter. Water from shallow, muddy or marshy surface shall not be permitted. The intake pipe shall be enclosed to exclude silt, mud, grass and other solid materials and there shall be a minimum depth of 0.60 m of water below the intake at all times.

1015 TESTS AND STANDARD OF ACCEPTANCE

All materials, even though stored in an approved manner shall be subjected to an acceptance test in accordance with the relevant IS specification prior to their immediate use.

Independent testing of cement for every consignment shall be done by the Contractor at site in the laboratory approved by the Engineer before use. Any cement with lower quality than those shown in manufacturer's certificate shall be debarred from use. In case of imported cement, the same series of tests shall be carried out before acceptance.

1015.1 Testing and Approval of Material

The Contractor shall furnish test certificates from the manufacturer/supplier of materials along with each batch of material(s) delivered to site.

The Contractor shall set up a field laboratory with necessary equipment for testing of all materials, finished products used in the construction as per requirements of conditions of

contract and the relevant specifications. The testing of all the materials shall be carried out by the Engineer or his representative for which the Contactor shall make all the necessary arrangements and bear the entire cost.

Test which cannot be carried out in the field laboratory have to be got done at the Contractor's cost at any recognized laboratory / testing establishments approved by the Engineer.

1015.2 Sampling of Materials

Samples provided to the Engineer or his representative for their inspection are to be in labeled boxes suitable for storage.

Samples required for approval and testing must be supplied well in advance by at least 48 hours or minimum period required for carrying out relevant tests to allow for testing and approval. Delay to works arising from the late submission of samples will not be acceptable as a reason for delay in the completion of the works.

If materials are brought from abroad, the cost of sampling/testing whether in India or abroad shall be borne by the Contractor.

1015.3 Rejection of Materials not Conforming to the Specifications.

Any stack or batch of material(s) of which sample(s) does not conform to the prescribed tests and quality shall be rejected by the Engineer or his representative and such materials shall be removed from site by the Contractor at his own cost. Such rejected materials shall not be made acceptable by any modifications.

1015.4 Testing and Approval of Plant and Equipment

All plants and equipment used for preparing, testing and production of materials for incorporation into the permanent works shall be in accordance with manufacturer's specifications and shall be got approved by the Engineer before use.

1100

Pile Foundations

1101 DESCRIPTION

1101.1 This work shall consist of construction of all types of piles for structures in accordance with the details shown on the drawings and conforming to the requirements of these Specifications as directed by the Engineer.

1101.2 The construction of pile foundations requires a careful choice of the piling system depending upon sub-soil conditions and loading characteristics and type of structure. The permissible limits of total and differential settlements, unsupported length of pile under scour, impact/entanglement of floating bodies and any other special requirements of project are also equally important criteria for selection of the piling system. The method of installing the piles, including details of the equipment shall be submitted by the Contractor and got approved from the Engineer before commencement of work.

1101.3 The work shall be done as per IS:2911 except as modified herein.

1102 SUB-SURFACE INVESTIGATIONS

1102.1 The complete sub-surface investigations of strata in which pile foundations are proposed shall be carried out in advance along with in-situ pile tests. For details of geo-technical sub-surface explorations, reference may be made to Section 2400. At least one bore hole for every foundation of the bridge shall be carried out. Borings should be carried upto sufficient depths so as to ascertain the nature of strata around the pile shaft and below the pile tip. However, depth of boring shall not be less than :

i) 1.5 times estimated length of pile in soil but not less than 1.5 m below the proposed founding level

ii) 15 times diameter of pile in weak/jointed rock but minimum 15 m in such rock

iii) 4 times diameter of pile in sound, hard rock but minimum 3 m in such rock

1102.2 The sub-surface investigations shall define adequately stratification of sub-strata including the nature and type of strata, its variation and extent and specific properties of the same. The investigations shall be adequate for the purpose of selection of appropriate piling system and for estimating design capacities for different diameters and length of piles.

1102.3 Pressure meter tests may be used in the case of rock, ground or soil for direct evaluation of strength and compressibility characteristics. Though these tests are of specialized nature they are more appropriate for difficult/uncertain sub-strata especially for important projects.

1102.4 For piles socketed into rocks, it is necessary to determine the uni-axial compressive strength of the rock and its quality.

The investigations shall also include location of ground water table and other parameters including results of chemical tests showing sulphate and chloride content and any other deleterious chemical content in soil and/or ground water, likely to affect durability.

1103 TYPE OF PILES

The piles may be of reinforced concrete, prestressed concrete, steel or timber. The piles may be of solid or hollow sections or steel cased piles filled with concrete. Timber piles may be used for temporary bridges. Concrete piles may be driven cast-in-situ or precast or bored cast-in-situ or precast piles driven into performed bores. The shape of piles may be circular, square, hexagonal, octagonal, “H” or “I” Section.

1103.2 Minimum diameter of concrete pile shall be 1m for river / marine bridges. For bridges beyond the water zone and bridges on land, the diameter may be reduced to 750 mm.

1104 MATERIALS

1104.1 The basic materials shall conform to the specifications for materials given in Section 1000. The specifications for steel reinforcement, structural concrete, prestressed concrete and structural steel to be used in pile foundations shall be as given in the relevant sections.

1104.2 Concrete in Piles

For both pre-cast and cast in in-situ piles, the grade of concrete, minimum cement content, water cement ratio and slump shall be as per Table 1100-1 :

Table 1100-1 Requirements for Concrete in Piles

	Cast in-situ concrete by Tremie	**Pre-cast Concrete**
Grade of concrete	M 35	M 35
Minimum cement content	400 kg / m^3	400 kg/m^3
Minimum water cement ratio	0.40	0.40
Slump (mm)	150-200	75-150

In marine conditions and areas exposed to action of harmful chemicals, protection of pile caps with suitable coatings such as bituminous based coat for epoxy, epoxy based coating

may be carried out. High alumina cements (i.e. quick setting cement) shall not be used in marine conditions. When both chlorides and sulphates are present, sulphate resistant cement should not be used. For improving resistance to penetration of harmful elements from soils, use of mineral admixtures like fly ash, silica fumes, GGBS conforming to respective BIS/International Standards and as per IRC:21 may be made.

1105 TEST PILES

1105.1 Test piles which are shown on the drawings or specified in the contract or installed by the Contractor on his own to determine the lengths of piles to be furnished shall conform to the requirements for piling as indicated in these Specifications, if they are to be incorporated in the completed structure.

All test piles shall be installed with the same type of equipment that is proposed to be used for piling in the actual structure.

Test piles which are not to be incorporated in the completed structure shall be removed to at least 600 mm below the proposed soffit level of pile cap and the remaining hole shall be backfilled with earth or other suitable material.

The piles shall be load tested in accordance with provisions laid down in this section.

1106 PRECAST CONCRETE PILES

1106.1 General

Precast concrete piles shall be of the size and shape as shown in the approved drawings. If a square section is employed, the corners shall be chamfered at least 25 mm unless otherwise specified on the drawings. The length of pile shall not normally exceed 25 m. However, where special equipments for handling and installation are available to the satisfaction of the Engineer, longer length could be permitted.

Piles shall be cast with a driving point and for hard driving, shall be shod with a metal shoe approved by the Engineer.

1106.2 Stacking, Storing and Handling

Care shall be taken that at all stages of transporting, lifting and handling, piles are not damaged or cracked. During transport and stacking of piles, they shall be supported at the same points as those provided for lifting purposes. If the piles are put down temporarily during handling, they shall be placed on trestles or blocks located at the same points.

Piles shall be stored at least 300 mm above firm level ground, which is not liable to unequal subsidence or settlement under the weight of the stack of piles. They shall be placed on

timber supports which are level and spaced so as to avoid bending. The supports shall be vertically one above the other. Spaces shall be left round the piles to enable them to be lifted without difficulty. The order of stacking shall be such that the older piles can be withdrawn without disturbing newer piles. Separate stacks shall be provided for different lengths of piles. Where piles are stacked in layers, the number of layers shall not exceed three. Whenever curing is needed during storage, arrangements shall be made to enable the piles to be watered. For detailed precautions with regard to curing operations specifications for structural concrete given in Section 1700 shall apply.

Before the operation of handling and driving the piles, the minimum periods counted from the time of casting shall be allowed for as indicated in Table 1100-2. Prestressed pile shall not be lifted or handled until fully stressed.

TABLE 1100-2 TIME FOR CURING PRECAST PILES

Type of cement used in casting the pile	Minimum periods from time of casting			
	Strike side-shutters (hours)	End of wet curing (days)	Lift from casting bed (days)	Drive (days)
Ordinary Portland	24	7	10	28
Rapid hardening Portland	12	7	7	10

1106.3 Lengthening of Piles

Where a pile is to have another length cast on it during driving, the longitudinal reinforcement shall preferably be joined by full penetration butt welding. The concrete at the top of the original pile shall be cut down to expose not less than 200 mm of the bars to avoid spalling of the concrete by heat. The added bars have to be held accurately and rigidly in position during welding. Where facilities on site are insufficient to make proper butt welding practicable, the joint may be made by lapping. The reinforcement at the head of pile will need to be exposed for full anchorage length or 600 mm whichever is greater and the new bars over-lapped for this distance. Unless otherwise specified, the extension of the pile shall be formed to the same cross-sectional profile and with concrete of at least the same strength as that specified for the original pile. The stirrup spacing shall in no case be greater than 150 mm. Not more than one extension shall be permitted. In case more than one extension is permitted by the Engineer, only approved chemical couplers shall be used.

Driving shall not be resumed until:

a) the strength of the concrete in the extension is at least equal to the specified characteristic strength of concrete in pile; and

b) the approval of the Engineer has been obtained.

1106.4 Removal of Surplus Length

Any length of pile surplus to that required for incorporation in the structure shall be cut off neatly and removed. During the process of cutting off, it shall be ensured that projecting reinforcement to be anchored into the pile cap and the prestressing strands/wires are not damaged. When stripping prestressed concrete piles, shock release of tendons shall be avoided. Reference may also be made to Clause 7.7.1 of IS:2911 (Part I, Section 3) in this connection.

1106.5 Risen Piles

Level reading should be taken on each pile after driving and again after all the piles are driven. Piles which are found to have risen due to ground heave or as a result of driving adjacent piles, shall be re-driven to the original depth or resistance unless re-driving tests on adjacent piles have shown this to be unnecessary.

1106.6 Manufacture

The pile should be cast in one continuous operation from end to end of each pile. Manufacture of precast concrete piles shall conform to the guidelines contained in Clause 7.1, 7.2 and 7.3. or IS:2911 (Part I, Section 3).

Pile shall be provided with suitable shoe for protecting the point of the pile during driving in hard ground.

Piles shall not be moved from casting bed until the concrete has hardened sufficiently.

Piles shall not be driven in less than 28 days after casting or unless their strength at the time of driving is at least that specified for 28 days.

1106.7 Prestressed Concrete Piles

Additional specifications for precast prestressed concrete piles shall conform to those contained in Clause 8 of IS:2911 (Part I, Section 3).

1107 CAST-IN-SITU CONCRETE PILES

Cast-in-situ concrete piles may be either installed by making a bore into the ground by removal of material or by driving a metal casing with a shoe at the tip and displacing the material laterally. The two types of piles are termed as “bored piles” and “driven piles” respectively. Cast-in-situ concrete piles may be cast in metal shells which may remain permanently in place. However, other types of reinforced concrete cast-in-situ piles, , cased or uncased, may be used if in the opinion of the Engineer the soil conditions permit their use and if their design and the methods of placing are satisfactory.

The metal casing shall be of sufficient thickness and strength to hold its original form and show no harmful distortion after it and adjacent casings have been driven and the driving core, if any, has been withdrawn.

Cast-in-situ concrete driven piles shall be installed using a properly designed detachable shoe at the bottom of the casing. Certain specific requirements of cast-in-situ driven piles shall be as per Clauses 1110 and 1111.

Any liner or bore-hole which is improperly located or shows partial collapses that would affect the load carrying capacity of the pile, shall be rejected or repaired as directed by the Engineer at the cost of the Contractor.

Wherever practicable, concrete should be placed in a clean dry hole. Where concrete is placed in dry and there is casing present, the top 3 m of the pile shall be compacted using internal vibrators. The concrete should invariably be poured through a tremie with a funnel so that the flow is directed and concrete can be deposited in the hole without segregation.

Where the casing is withdrawn from cohesive soils for the formation of cast-in-situ pile, the concreting should be done with necessary precautions to minimise the softening of the soil by excess water. Where mud flow conditions exist, the casing of cast-in-situ piles shall not be allowed to be withdrawn.

Care shall be taken during concreting to prevent as far as possible the segregation of the ingredients. The displacement or distortion of reinforcement during concreting and also while extracting the tube.

If the concrete is placed inside precast concrete tubes or consists of precast sections, these shall be free from cracks or other damage before being installed.

The concrete shall be properly graded, shall be self-compacting and shall not get mixed with soil, excess water, or other extraneous matter. Special care shall be taken in silty clays and other soils with the tendency to squeeze into the newly deposited concrete and cause necking. Sufficient head of green concrete shall be maintained to prevent inflow of soil or water into the concrete.

The placing of concrete shall be a continuous process from the toe level to the top of the pile. To prevent segregation, a tube or tremie tube as appropriate shall be used to place concrete in all piles.

To ensure compaction by hydraulic static heads, rate of placing concrete in the pile shaft shall not be less than 6 m (length of pile) per hour.

Bored cast-in-situ piles in soils which are stable, may often be installed with only a small

casing length at the top. A minimum of 10 m length of top of bore shall invariably be provided with casing to ensure against loose soil falling into the bore. In cases in which the side soil can fall into the hole, it is necessary to stabilize the side of the bore hole with drilling mud, or a suitable steel casing. Permanent steel liner should be provided at least up to maximum scour level. In case of marine clay or soft or soil having aggressive material, permanent steel liner of sufficient length shall be provided up to full length of such strata. The minimum thickness of steel liner shall be 6 mm.

For bored cast-in-situ piles, casing/liner shall be driven open ended with a pile driving hammer capable of achieving penetration of the liner to the length shown on the drawing or as approved by the Engineer. Materials inside the casing shall be removed progressively by air lift, grab or percussion equipment or other approved means.

Where bored cast-in-situ piles are used in soils liable to flow, the bottom of the casing shall be kept enough in advance of the boring tool to prevent the entry of soil into the casing, thus preventing the formation of cavities and settlements in the adjoining ground. The water level in the casing should generally be maintained at the natural ground water level for the same reasons. The joints of the casing shall be made as tight as possible to minimize inflow of water or leakage of slurry during concreting.

Boring shall be carried out using rotary or percussion type equipment. Unless otherwise approved by the Engineer, the diameter of the bore-holes shall be not more than the inside diameter of the liner.

Prior to the lowering of the reinforcement cage into the pile shaft, the shaft shall be cleaned of all loose materials. Cover to reinforcing steel shall be maintained by suitable spacers.

The diameter of the finished pile shall not be less than that specified and a continuous record shall be kept by the Engineer as to the volume of concrete placed in relation to the pile length cast.

Concreting shall be done by tremie method. In tremie method, the following requirements are particularly applicable:

a) When concreting is carried out for a pile, a temporary casing should be installed to sufficient depth, so that fragments of ground cannot drop from the sides of the hole into the concrete as it is placed. The temporary casing is not required except near the top when concreting under drilling mud.

b) The hopper and tremie should be a leak proof system.

c) Tremie diameter of minimum 200 mm shall be uesd with 20 mm diameter down aggregate.

d) The first charge of concrete should be placed with a sliding plug pushed down the tube ahead of it or with a steel plate of adequate charge to prevent mixing of concrete and water. However, the plug should not be left in the concrete as a lump.

e) The tremie pipe should always penetrate well into the concrete with an adequate margin of safety against accidental withdrawal of the pipe. The tremie should be always full of concrete.

f) The pile should be concreted wholly by tremie and the method of deposition should not be changed part way up the pile, to prevent the laitance from being entrapped within the pile.

g) All tremie tubes should be scrupulously cleaned after use.

h) As tremie method of concreting is not under water concreting, there is no need to add 10 percent extra cement.

i) Normally, concreting of the piles should be uninterrupted. In the exceptional case of interruption of concreting, but which can be resumed within 1 or 2 hours, the tremie shall not be taken out of the concrete. Instead, it shall be raised and lowered slowly, from time to time to prevent the concrete from setting. Concreting should be resumed by introducing a little richer concrete with a slump of about 20 mm for easy displacement of the partly set concrete.

j) In case of withdrawal of tremie out of the concrete, either accidentally or to remove a choke in the tremie, the tremie may be reintroduced in the following manner to prevent impregnation of laitance or scum lying on the top of the concrete already deposited in the bore.

k) The tremie shall be gently lowered on to the old concrete with very little penetration initially. A vermiculite plug / surface retarders should be introduced in the tremie. Fresh concrete slump between 150 mm to 175 mm should be filled in the tremie which will push the plug forward and will emerege out of the tremie displacing the laitance/scum. The tremie will be pushed further in steps making fresh concrete sweep away laitance/scum in its way. When tremie is buried by about 60 to 100 cm, concreting may be resumed.

l) The ‘L’ bends in the reinforcements at the bottom of the piles should not be provided to avoid the formation of soft toe.

Removal of concete above cut-off level

It is desirable that the concrete above cut off level is removed before the concrete is set. The concrete may be removed manually or by specially made bailer or other device. Such removal of concrete helps in preventing the damages of the good concrete below the cut off level which results from chipping by percussion method.

The removal of concrete may be within the ± 25 mm from the specified cut off level preferably on the (-) side. On removal of such concrete, the concrete shall be compacted with rammer with spikes or it shall be vibrated.

In case the concrete is not removed before setting, a groove shall be made on outer perimeter by rotary equipment before chipping by percussion method.

The minimum embedment of cast-in-situ concrete piles into pile cap shall be 150 mm. Any defective concrete at the head of the completed pile shall be cut away and made good with new concrete. The clear cover between the bottom reinforcement in pile cap from the tip of the pile shall be not less than 25 mm. The reinforcement in the pile shall be exposed for full anchorage length to permit it to be adequately bonded into the pile cap. Exposing such length shall be done carefully to avoid damaging the rest of the pile. In cases where the pile cap is to be laid on ground, a leveling course of M 15 nominal mix concrete 100 mm thick shall be provided. Defective piles shall be removed or left in place as judged convenient without affecting the performance of adjacent piles or pile cap. Additional piles shall be provided to replace the defective piles.

1108 STEEL PILES

Steel piles shall be “H” or “I” sections as shown on the drawings and shall be of structural steel conforming to the Specifications given in Section 1000.

Steel piles shall be protected by suitable anti-corrosive painting as specified on the drawing or as directed by the Engineer. Piles shall be stored above the ground having protective packing to minimize damage to surface coating. Each pile shall be supplied preferably in one piece without splices.

At the option of the Contractor, steel piles consisting of structural steel plates welded together may be substituted for the rolled sections specified, provided that the depth, width and average thicknesses are at least equal to those of the rolled sections, the steel plates conform to Specifications given in Section 1000, the flanges are welded to the web with continuous fillet welds on either side of the web, and the welding conforms to Clause 1904.8 of these Specifications.

The length of the steel pile may be built up in sections either before or during driving operations. The sections shall be of identical cross-section. Pile splices shall be made with full penetration butt welds over the whole cross-section. Pile splices shall develop at least the yield strength of pile.

The connections shall be made by butt-welding the entire cross-section in accordance with the provisions in Clause 1904.8 of these Specifications. Care shall be taken to properly align the sections connected so that the axis of the pile will be straight. The number of welded connections in the length of pile shall be as few as possible.

1109 TIMBER PILES

The Engineer shall stamp each pile on the butt with a stamp which shall make an impression that is readily legible. Treated timber piles will be inspected by the Engineer after treatment.

Untreated timber piles may be used as test piles.

Untreated timber piles shall be driven within 6 months after treatment.

Timber piles shall be furnished with tip protection and shall be protected by the use of steel straps as hereinafter specified. Tip protection shall be suitable for use on timber piling of the size to be driven. Details of tip protection shall be furnished to the Engineer for review and approval before driving piles. Not less than 2 separate steel straps shall be placed within 600 mm of the butt of each pile after the pile is square cut. Not less than 2 separate steel straps shall be placed within 300 mm of the tip of each pile. Additional intermediate steel straps shall be placed at not more than 3 m measured along the length of the pile.

Timber piles which are to be capped shall be separately cut off so that true bearing is obtained on every pile. Piles inaccurately cut off shall be replaced. Splicing of timer piles shall not be permitted except by written permission of the Engineer.

1110 DRIVING EQUIPMENT

Piles or their casings may be driven with any type of drop hammer, diesel hammer or single-acting steam or compressed air hammer, provided they penetrate to the prescribed depth to attain the designed resistance without being damaged. The weight or power of the hammer should be sufficient to ensure a penetration of at least 5 mm per blow unless rock has been reached. It is always preferable to employ the heaviest hammer practicable and to limit the stroke, so as not to damage the pile. The minimum weight of the hammer shall be 2.5t. In the case of precast concrete piles the mass of the hammer shall be not less than 30 times the mass of 300 mm length of pile.

Steam or air hammers shall be furnished along with boiler or air compressor of capacity at least equal to that specified by the manufacturer of the hammers. The boiler or air compressor shall be equipped with an accurate pressure gauge at all times. The valve mechanism and other parts of steam, air or diesel hammers shall be maintained in first class condition so that the length of stroke and number of blows per minute for which the hammer is designed, will be obtained. Inefficient steam, air or diesel hammers shall be removed from the work.

1111 DRIVING

1111.1 General Procedure

Details of the equipment and the method proposed for driving the piles shall be submitted for scrutiny and approval of the Engineer. Piles shall be installed from firm ground or from temporary supports or from fixed platform. The arrangement shall provide sufficient rigidity to ensure accuracy of pile driving under all conditions of tile, stream flow or hammer drop.

During driving the top of pile shall be protected by a suitable helmet of substantial steel construction. The helmet shall provide uniform bearing across the top of the pile and shall hold the pile centrally under the hammer. No pile shall be driven unless inspected and approved by the Engineer.

Piles shall be driven from a fixed frame of sufficient rigidity to ensure accuracy of driving within specified tolerances. Forces producing undue bending or torsional stresses in piles shall not be applied during driving. The force of the hammer shall be directed centrally and axially during driving.

The stroke of a single acting or drop hammer shall be limited to 1.2 m unless otherwise permitted by the Engineer. A shorter stroke may be necessary when there is danger of damaging the pile.

Piles shall not be bent or sprung into position but shall be effectively guided and held on-line during the initial stages of driving. Attempts to correct any tendency for the pile to run off-line by the application of significant horizontal restraint will not be permitted. Shortly after the commencement of driving and at regular intervals throughout the driving operation, checks shall be made to ensure that the pile frame does not exert any undue lateral force on the pile due to restraint within the helmet.

If the indications are that a pile will finish outside the specified tolerances, driving operations on that pile will cease. The pile shall be withdrawn, the hole filled and the pile re-driven at no extra cost to the Employer.

To avoid the possibility of premature “set-up” pile driving shall be continuous in the later stages, without any deliberate stops. (delays of an hour or less may lead to significant “set-up” in piles i.e. resistance to further driving increases after driving is stopped).

If any pile is damaged in any way during driving, it shall be repaired or replaced as directed by the Engineer, at the cost of Contractor. If during driving, the head of a pile is damaged to the extent that further driving is not possible, the head shall be cut off and driving continued. The cost of cutting off shall be borne by the Contractor and where, as a result of such cutting off the head, the pile is too short, the Contractor, shall, at his own cost, supply and splice on sufficient length of pile to restore the pile to its correct length.

Piles should be driven to the minimum acceptable penetration shown on the drawings. This may require preboring and/or jetting as indicated in these Specifications with the approval of the Engineer.

Piles shall be driven to nominal refusal or the required ultimate dynamic capacity nominated on the drawings or until the top of the pile is at the level required and specified on the drawing whichever gives the lowest toe elevation. The Engineer's decision in these matters shall be final. Nominal refusal shall be taken as equivalent to 25 mm total penetration for the final 20 blows using a hammer of driving energy as specified and shall be used as the criterion for acceptance for piles founded on rock. Severe driving which results in an average set per blow less than 0.5 mm will not be permitted.

Where hard drilling is encountered because of dense strata or obstructions located above the predetermined pile tip level, nominal refusal shall not be considered to have been achieved unless the Engineer is satisfied that the total number of blows, as the average driving resistance specified for nominal refusal, indicates that further driving will not advance the pile through dense strata or obstructions.

The pile shall be driven as accurately as possible to the vertical or to specified batter. Straining the pile into position can damage it and the driving equipment should be adjusted as much as possible to follow the position of the pile. Any deviation from the proper alignment shall be noted and promptly reported to the Engineer. If the deviation is to such an extent that the resulting eccentricity cannot be taken care of by strengthening the pile cap or pile tips, such a pile shall, at the discretion of the Engineer, be replaced or supplemented by an additional pile. Unless otherwise specified, the permissible positional deviation for piles shall be limited to those indicated in Clause 1116.

Care shall be taken not to damage the pile by over-driving. Any sudden change in the rate of penetration which cannot be ascribed in the nature of the ground shall be noted and its cause ascertained, if possible, before driving is continued.

When employing a tube which is subsequently withdrawn for the formation of cast-in-situ pile, consideration shall be given to the possibility of doing harm to a pile recently formed by driving the tube nearby before the concrete has sufficiently set. The danger of doing harm is greater in compact soils than loose soils. No pile shall be bored or driven within 3 m of a newly cast pile until at least 24 hours after completion of its installation.

Driving piles in loose sand tends to compact the sand which in turn increases the skin friction. Therefore, driving a number of friction piles in a group shall proceed outward from the centre as otherwise it will be difficult to drive the inner piles to the same depth as the others.

In the case of stiff clay also, the driving for a group of piles shall proceed outward from the centre. However, in case of very soft soil, the driving may proceed from outside to inside, so that the soil is restrained from flowing out during driving operations.

If there is a major variation between the depth at which adjacent foundation piles in a group meet refusal, a boring shall be made nearby to ascertain the cause of this difference. If the boring shows that the soil contains pockets of highly compressive material below the level of the shorter pile, it will be necessary to enforce penetration of all the piles to a level below the bottom of the zone which shows such pockets.

1111.2 Preboring and Jetting

Driving of the piles may be assisted by preboring holes or by the use of jets or both subject to the approval of the Engineer. These may be used essentially to achieve the minimum penetration shown on the drawings where such penetration is not reached under normal conditions of driving indicated in Clause 1111.1.

The diameter of the hole shall not be greater than the diagonal dimension of the pile less 100 mm.

The maximum depth of the preboring shall be such that the specified set (or less) is obtained when the toe of the pile is at founding level. Preboring shall be as approved by the Engineer and shall not extend below one metre above the founding level and the pile shall be driven to at least one metre below the prebored hole. To ensure that the pile is properly supported laterally in the hole, any space remaining around the pile at the ground level after driving is finished shall be backfilled with approved granular material.

When water jetting is used, at least two jets shall be attached to the pile symmetrically when this type of technique is used. The volume and pressure of water at the outlet nozzles shall be sufficient to freely erode material adjacent to the toe of the pile. The maximum depth of jetting shall be such that the specified set (or less) is obtained when the toe of the pile is at founding level. Jetting shall cease as directed by the Engineer and shall not proceed below one metre above the founding level and the pile shall be driven at least one metre below the pre-bored hole.

To avoid very hard driving and vibration in materials such as sand, jetting of piles by means of water may be carried out only by express permission of the Engineer and in such a manner as not to impair the bearing capacity of piles already in place, the stability of the soil or the safety of any adjoining buildings. Details of the arrangement for jetting shall be got approved from the Engineer in advance.

If, for jetting, large quantities of water are used, it may be necessary to make provision for collection of water when it comes to the ground surface, so that the stability of the piling plant is not endangered by the softening of the ground.

Jetting shall be stopped before completing the driving which shall always be finished by ordinary methods. Jetting shall be stopped if there is any tendency for the pile tips to be drawn towards the pile already driven owing to the disturbance to the ground.

1112 RAKER (INCLINED) PILES

The maximum rake to be permitted in piles shall not exceed the following:

i) 1 in 6 for all bored piles

ii) 1 in 6 for cast-in-situ piles

iii) 1 in 4 for precast driven piles

1113 PILE TESTS

1113.1 Requirement and steps for design and installation of piles

The initial design of an individual pile, confirmation of its capacity by either initial load test or by re-confirmation of actual soil, parameters, modification of design, if required and the final adoption should pass through following steps of investigations, design and load testing:

i) Comprehensive and detailed sub-surface investigation for piles to determine the design parameters of end bearing capacity, friction capacity and lateral capacity of soil surrounding the pile.

ii) Design of pile and pile group based on (i) above for specified bearing strata.

iii) Initial load testing. Initial load test on pile of same diameter as design pile for direct confirmation of design. The initial load test is a part of the design process confirming the expected properties of bearing strata and the pile capacity.

iv) Step (ii) & (iii) should be repeated for different types of strata met at site.

The steps for design and confirmation by tests are given below:

i) Sub-soil exploration to re-confirm soil parameters assumed in the design.

ii) Provide for the required design capacity of pile group based on tentative number and diameter of piles in a group.

iii) The allowance total/differential settlement of single pile should be based on the considerations as per Clauses 709.1.8 and 709.3.4 of IRC:78. Capacity of single pile is to be based on static formula considering ground characteristics. This step along with step (ii) may be iterative.

iv) Structural design of piles.

v) Initial load test for axial load capacity, including uplift capacity if required, on trial piles of the same diameter as the design pile should be carried out. The testing shall be done as per the procedure laid down in IS:2911, Part-IV. The load test shall be conducted for not less than 2½ times the design load. The initial load test shall be cyclic load test for piles deriving strength from end bearing and side friction. The maintained load test can be performed for end bearing piles without relying on friction and for the socketed piles in rock;

vi) If the initial load test gives a capacity greater than 25 percent of the capacity calculated by static formula and if it is desired to take benefit of the higher capacity, another two load tests shall be carried out to confirm the earlier value and minimum of the three shall be considered as initial load test value. The number of initial tests shall be determined by the Engineer taking into consideration the bore log and soil profile.

1113.2 Routine Load Tests

Routine load test should be done at actual locations of foundations of bridges to re-confirm or modify the allowable loads. Vertical and horizontal load tests should be properly designed to cover particular pile group. The lateral load test may be conducted on two adjacent piles. However, results of routine load tests shall not be used for upward revision of design capacity of piles. The minimum number of tests to be conducted for confirming the capacity shall be as per Table 1100-3 :

Table 1100-3 Minimum Numebr of Tests

Total number of piles for the bridge	**Minimum number of test piles**
Upto 50	2
50-150	3
Beyond 150	2% of total piles (fractional number rounded to next higher integer number)

Note: The number of tests may be judiciously increased depending upon the variability of foundation strata.

1113.3 Permissible over load

While conducting routine test on one of the piles belonging to a pile group, the pile is found to be deficient (based on the settlement criteria at 1.5 times the test load) an overload up to 10 percent of the capacity may be allowed.

1113.4 For a quick assessment of pile capacity, strain dynamic tests may be conducted after establishing co-relation using the results of load tests. However, results of strain dynamic tests shall not be used for upward revision of design capacity of pile. Detailed guidelines and references are at *Appendix-7 Parts 1 & 2*. These methods can be followed.

To have a fairly good idea about the quality of concrete and construction defects like voids, discontinuities etc, pile integrity tests are extensively conducted. Detailed guidelines in this connection are given in IRC:78.

1114 PILE CAP

Casting of pile cap should be at a level higher than water level unless functionally required to be below water level at which time sufficient precautions shall be taken to de-water to allow concreting in dry conditions. Pile caps shall be of reinforced concrete. A minimum offset of 150 mm shall be provided beyond the outer faces of the outermost piles in the group. If the pile cap is in contact with earth at the bottom, a leveling course of minimum 100 mm thickness of M 15 nominal mix concrete shall be provided. In marine conditions or areas exposed to the action of harmful chemicals, the pile cap shall be protected with a suitable anti-corrosive paint. High alumina cement, i.e. quick setting cement shall not be used in manufacture of concrete in marine environment.

The attachment of the pile head to the cap shall be adequate for the transmission of loads and forces. A portion of pile top may be stripped of concrete and the reinforcement anchored into the cap. Manual chipping may be permitted after three days of pile casting, while pneumatic tools for chipping shall not be used before seven days after pile casting. The top of pile after stripping shall project at least 150 mm into the pile cap. A layer of surface reinforcement may be provided with a cover of 25 mm to retain the integrity of concrete below the main cap reinforcement which is to be laid 25 mm above the pile top.

The top of concrete in a pile shall be brought above cut-off level to permit removal of all laitance and weak concrete before pile cap is laid. This will ensure good concrete at the cut-off level.

1115 IMPORTANT CONSIDERATIONS, INSPECTION/ PRECAUTIONS FOR DIFFERENT TYPES OF PILES

1115.1 Driven Cast-in-Situ Piles

1115.1.1 Specialist literature and the guidelines from the pile construction industry shall be consulted regarding the method of installation, equipment and accessories for pile driving and recording of data.

1115.1.2 During installation of piles, the final "set" of penetration of pile per blow of hammer shall be checked taking an average of last 10 blows.

1115.1.3 The pile shoes which may be of either cast iron conical type or mild steel flat type shall have double reams for proper seating of the removable casing tube inside the space between the reams.

1115.1.4 Before commencement of pouring of concrete, it shall be ensured that there is no ingress of water in the casing tube from the bottom. Further, adequate control during withdrawal of the casing tube is essential so as to maintain sufficient head of concrete inside the casing tube at all stages of withdrawal.

1115.1.5 Concrete in piles shall be cast upto a minimum height of 600 mm above the designed top level of pile, which shall be striped off at the time of construction of pile cap.

1115.2 Bored Cast-in-Situ Piles

1115.2.1 While concreting uncased piles, voids in concrete shall be avoided and sufficient head of concrete is to be maintained to prevent inflow of soil or water into the concrete. It is also necessary to take precautions during concreting to minimize the softening of the soil by excess water. Uncased cast-in-situ piles shall not be allowed where mudflow conditions exist.

1115.2.2 The drilling mud such as bentonite suspension shall be maintained at a level sufficiently above the surrounding ground water level to ensure the stability of the strata which is being penetrated throughout the boring process until the pile has been concreted.

1115.2.3 Where bentonite suspension is used to maintain the stability of the bore-hole, it is essential that the properties of the material be carefully controlled at stages of mixing, supply to the bore-hole and immediately before concrete is placed. It is usual to limit :

i) The density of bentonite suspension to 1.05 g/cc

ii) The marsh cone viscosity between 30 and 40

iii) The pH value between 9.5 and 12

iv) The silt content less than 1 per cent

v) The liquid limit of bentonite not less than 400 percent

These aspects shall act as controlling factors for preventing contamination of bentonite slurry for clay and silt.

1115.2.4 The bores shall be washed by bentonite flushing to ensure clean bottom at two stages viz. after completion of boring and prior to concreting after placing of

reinforcement cage. Flushing of bentonite shall be done continuously with fresh bentonite slurry till the consistency of inflowing and out-flowing slurry is similar.

1115.2.5 Tremie of 150 mm to 200 mm diameter shall be used for concreting. The tremie should have uniform and smooth cross-section inside, and shall be withdrawn slowly ensuring adequate height of concrete outside the tremie pipe at all stages of withdrawal. Other recommendations for tremie concreting are :

i) The sides of the bore-hole have to be stable throughout.

ii) The tremie shall be water-tight throughout its length and have a hopper attached at its head by a water-tight connection.

iii) The tremie shall be large enough in relation to the size of aggregates. For 20 mm aggregates the tremie pipe shall be of diameter not less than 150 mm and for larger size aggregates tremie pipe of larger diameter is required.

iv) The tremie pipe shall be lowered to the bottom of the bore-hole, allowing water or drilling mud to rise inside it before pouring concrete.

v) The tremie pipe shall always be kept full of concrete and shall penetrate well into the concrete in the bore-hole with adequate margin of safety against accidental withdrawal if the pipe is surged to discharge the concrete.

1115.2.6 For very long or large diameter piles, use of retarding plasticizer in concrete is desirable.

1115.2.7 For large diameter piles, it may be essential to conduct non-destructive pile integrity tests to evaluate integrity of the pile.

1115.2.8 Where possible, it may be desirable to grout the base of pile with cement slurry under suitable pressure after concrete in the pile attains the desired strength. For this purpose, conduit pipes with easily removable plugs at the bottom end should be placed in the bore alongwith reinforcement cage before concreting.

1116 TOLERANCES

1116.1 Permissible Tolerances for Piles

i) Precast Concrete Piles:

a) Variation in cross-sectional dimensions : ± 5 mm

b) Variation in length : ± 25 mm

c) Surface irregularities measured with 3 m straight edge : 5 mm

d) Bow for length in mm : Pile Length in 1000 mm

ii) Driven Piles

a) Variation in cross-sectional dimensions : +50 mm, -10 mm

b) Variation from vertical or specified rake : 1 in 50

c) For vertical piles 75 mm at piling platform level and tilt not exceeding 1 in 150 : 75 mm

d) Variation of level of top of piles : ± 25 mm

iii) Bored Piles

a) Variation in cross-sectional dimensions : +50 mm, -10 mm

b) Variation from vertical or specified rake : 1 in 50

c) For vertical piles 75mm at piling platform level and tilt not exceeding 1 in 150 : 50 mm

d) Variation of level of top of piles : ± 25 mm

(iv) For raker piles : 1 in 25

1116.2 Permissible Tolerances for Pile Caps

a) Variation in dimensions : +50 mm, -10 mm

b) Misplacement from specified position in plan : 15 mm

c) Surface irregularities measured with 3 m straight edge : 5 mm

d) Variation of level of top of piles : ± 25 mm

1117 TESTS AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria and requirements.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

1118 MEASUREMENTS FOR PAYMENT

For supply of precast concrete, timber or steel piles of specified cross-secton, the measurement shall be in metres of the length of piles ordered in writing by the Engineer measured from the head to the butt of the shoe or the tapered point. Reinforcement in precast concrete piles shall not be measured for payment.

For cast-in-situ driven and bored concrete piles of specified cross-section, the measurement shall be the length in metres of the accepted pile that remains in the finished structure complete in place. Reinforcement in cast-in-situ driven and bored concrete piles shall be measured for payment as per Section 1600.

Routine and Initial Pile Load Tests shall not be measured for payment.

For installation of the pile, i.e. by drilling in the case of precast concrete, timber, steel and cast-in-situ driven piles, and by boring in the case of cast-in-situ boed pile the measurement shall be the length in metres that remains in the finished structure complete in place, limited to that shown on drawings or ordered by the Engineer. No distinction shall be made for penetration through hard strata or rock and socketing into rock.

For steel liners/casing shown on the drawings to be permanently left in place, the measurement shall be by weight in tonnes that remains in the finished structure complete in place, limited to that shown on drawings or ordered by the Engineer.

For the pile cap, the quantity of concrete shall be measured in cubic metres as per Section 1700. While reinforcement in pile cap shall be measured in tonnes as per Section 1600.

1119 RATE

The contract unit rate for supplying precast concrete, timber or steel piles shall include cost of all labour, materials, tools and equipment, and other work involved in making or fabricating the pile complete as shown on the drawing, and where required its loading, transport, delivery to site, unloading and stacking it at the place indicated by the Engineer. The cost of reinforcement as per Section 1600 in precast concrete shall be deemed to be included in the quoted rate for supply of piles.

The contract unit rate for cast-in-situ driven and bored piles shall include the cost of concrete and all other items as per Section 1700. The contract unit rate shall also include costs of all labour, materials, equipments and all other incidentals involved in conducting routine and initial pile load tests including installation of piles for initial load tests.

The contract unit rate for reinforcement in cast-in-situ driven and bored piles shall be as per Section 1600.

The contract unit rate for installation of piles shall include full compensation for furnishing all labour, materials, tools and equipment, and incidentals for doing all the works involved in driving timber, precast concrete and steel piles, driving or making bores for cast-in-situ driven and bored concrete piles, cutting off pile heads, all complete in place to the specified penetration of piles. Providing temporary liner/casing and its withdrawal and placing reinforcement in position shall also be deemed to be included in the rate for installation of piles and no additional payment shall be made for the same.

The contract unit rate for permanent steel liners shall include cost of all labour, fabrication and placing the steel liner to the required depth as shown on the drawings and as ordered by the Engineer.

The contract unit rate for concrete in pile cap shall cover all costs of labour, materials, tools, plant and equipment, formwork and staging including placing in position, sampling and testing and supervision, all as per Section 1700. Reinforcement in the pile cap shall be paid for separately as per Section 1600.

1200

Well Foundations

1201 DESCRIPTION

This work shall consist of construction of well foundation, taking it down to the founding level through all kinds of sub-strata, plugging the bottom, filling the inside of the well, plugging the top and providing a well cap in accordance with the details shown on the drawings and as per these Specifications, or as directed by the Engineer.

In case of well foundations of size larger than 12 m diameter, supplemental construction specifications will be necessary.

1202 GENERAL

1202.1 Wells may have a circular, rectangular or D-shape in plan and may consist of one, two or more compartments in plan. The outer wall of the well, known as well steining may be cellular.

The process of taking down the well to the founding level is known as well sinking. After reaching the founding level, the hollow inside the well, ("dredge hole") is plugged at the bottom by concrete ("bottom plug"). The dredge hole is then filled with approved filling upto the level indicated on the drawings and provided with a concrete plug ("top plug").

To facilitate sinking of well, steel cutting edge is fabricated and connected to a concrete well curb of required shape. On top of the well curb, adequate height of well steining is cast and the process of sinking is carried out. After a portion of the well has been sunk, another height of well steining is cast on top of the previous section and further sinking carried out. This process is continued till the bottom level of the well reaches the founding level.

At the top of the well steining, well cap" is laid which transmits the loads and forces from the sub-structure (piers or abutments) to the foundations.

1202.2 At least one bore-hole must be available/carried out in accordance with these specifications at each well foundation location, prior to commencement of work. The depth of bore-holes should extend upto a depth equal to one and a half times the outer diameter/ least dimension of the well below the anticipated founding level. The results of soil exploration should be presented in accordance with Clause 704.3 of IRC:78. In case the well foundation is to rest on a rocky strata, it may be necessary to undertake additional borings/probings prior to commencement of work to ascertain the actual profile and the quality of the rocky strata, at the level at which the well has to be seated, etc.

1202.3 Blasting may have to be resorted to in order to facilitate sinking through difficult strata, such as boulders and rocks etc. In case blasting is anticipated, protective/ strengthening measures specified in Sub-Clause 6 of *Appendix 4* of IRC:78 shall be

taken. The grade of concrete in bottom 3 m of steining shall not be leaner than M 20 or as shown on the drawings.

1202.4 In case the bore hole data shows the presence of steeply dipping rock, chiseling may have to be resorted to so as to obtain proper seating of the foundation. For this purpose, the well may require to be dewatered completely under high air pressure inside the well. This process is known as pneumatic sinking. Pneumatic sinking may also have to be resorted to in cases where obstacles such as tree trunks, large sized boulders or hard strata etc. cannot be removed by open dredging. The necessity of adopting pneumatic sinking shall be decided by the Engineer.

The curb and steining have to be specifically designed for special loadings when pneumatic sinking is adopted.

1203 SETTING OUT AND PREPARATIONS FOR SINKING

1203.1 Necessary reference points shall be fixed, away from the zone of blow-ups or possible settlements resulting from well sinking operations. Such reference points shall be connected to the permanent theodolite stations with the base line on the banks. The center of the individual wells shall be marked with reference to these stations. The distance, wherever practicable, shall be checked with the help of accurate tapes and precision distomat.

Reference points shall also be fixed to mark X-X axis (usually traffic direction) and Y-Y axis (normal to X-X axis) accurately.

A temporary bench mark shall also be established near the well foundation, away from the zones of blow-ups or possible settlement. The bench mark shall be checked regularly with respect to the permanent bench mark established at the bridge site.

1203.2 For wells which are to be located in water, an earthen or sand island shall be constructed. Sand islands are practicable for water depths of about 5 m under stable bed soil conditions. For greater depths or in fast flowing rivers or for locations where soil is too weak to sustain sand island, floating caissons may have to be adopted.

The plan dimensions of sand islands shall be such as to have a working space of at least 2 m all around the steining. The dimension of the sand islands shall however be not less than twice the dimension in plan of the well or caisson. Sand islands shall be maintained to perform their functions, until the well is sunk to a depth below the bed level at least equal to the depth of water.

Sand island shall be protected against scour and the top level shall be sufficiently above the prevailing water level to be decided by the Engineer so that it is safe against wave action.

While sand islands are constructed at well location, floating caissons are generally fabricated at or near the banks on dry land or dry docks. Floating caissons are towed into position in floating condition.

Floating caissons may be of steel, reinforced concrete or a combination of the two. They should have at least 1.5 m free board above water level and increased, if considered necessary, in case there is a possibility of caissons sinking suddenly due to reasons such as scour likely to result from the lowering of caissons, effect of waves, sinking in very soft strata etc.

Stability of floating caissons shall be ensured against overturning and capsizing while being towed and during sinking for the action of water current, wave pressure, wind etc.

For floating caissons, a detailed method statement for fabrication, floating and sinking of caissons shall be prepared and furnished to the Engineer. Such statement shall include the total tonnage of steel involved, fabrication and welding specifications, list of materials and plant and a description of operations and manpower required for the work. The caisson shall be tested for leakages before being towed to site.

For well placed in the banks of the river or in the dry area, the bed may be prepared by excavating the soil up to 1.5 m followed by leveling and dressing before placing the cutting edge.

1203.3 Equipment

Equipment shall be deployed for construction of well foundation as required and as directed by the Engineer. Generally, the following equipments may be required for the work:

a) Crane with grab buckets – capacity 0.5 to 2.0 cu.m

b) Submersible pumps

c) Air compressors, air locks and other accessories where pneumatic sinking of well is anticipated

d) Chisels of appropriate sizes

e) Aqua-header for cutting rocky strata

f) Diving helmets and accessories

g) Equipments for concrete production, transportation and compaction

1204 CUTTING EDGE

1204.1 The mild steel cutting edge shall be made from structural steel sections and shall be strong enough to facilitate sinking of the well through the type of strata expected to be encountered. The weight of the cutting edge shall not be less than 40 kg per metre length and be properly anchored into the well curb, as shown in the drawing.

When there are two or more compartments in a well, the bottom end of the cutting edge of the inner walls of such wells shall be kept at about 300 mm above that of outer walls.

In V shaped cutting edge, the inclined plate should meet the vertical plate in such a way that full strength connection by welding is feasible.

1204.2 The parts of cutting edge shall be erected on level firm ground. Temporary supports shall be provided to facilitate erection and maintaining the assembly in true shape. The fabrication may be carried out in the shop or at site. Steel sections shall not be heated and forced into shape. However, "V" cuts may be made in the horizontal portion, uniformly throughout the length, to facilitate cold bending. After bending, such "V" cuts should be closed by welding. Joints in the lengths of structural sections, unless otherwise specified shall be filler welded using single cover plate to ensure the requisite strength of the original section.

1204.3 The cutting edge shall be laid about 300 mm above prevalent water level.

1205 WELL CURB

1205.1 The well curb shall be such that it shall offer minimum resistance while sinking, but shall be strong enough to be able to transmit superimposed loads from the steining to the bottom plug. The shape and the outline dimension of the curb as given in Appendix -3 (Fig. 2) of IRC:78 may be referred for guidance. The internal angle of the curb as shown in Appendix 3 shall be about 30^o to 37^o. depending upon geotechnical data.

The well curb may be pre-cast or cast-in-situ. The well curb shall be reinforced concrete of mix not leaner than M 25 with minimum reinforcement of 72 kg/cu.m excluding bond rod. The steel shall be suitably arranged to prevent spreading and splitting of curb during sinking. Steel formwork for well curb shall be fabricated strictly in conformity with the drawing. The outer face of the curb shall be vertical. The bottom ends of vertical bond rods of steining shall be fixed securely to the cutting edge with check nuts or by welds.

The formwork on outer face of curb may be removed within 24 hours after concreting. The formwork on inner face shall be removed after 72 hours. All concreting in the well curb shall be done in one continuous operation.

1205.2 In case blasting is anticipated, the inner faces of the well curb shall be protected with the steel plates of thickness not less than 10 mm up to the top of the well curb. If it is desired to increase the steel lining above the well curb then the thickness in the extended portion can be reduced to 6 mm. This extra height of the steel shall not exceed 3 m, unless specific requirement exists, as decided by the Engineer. The curb in cases involving blasting, shall be provided with additional hoop reinforcement consisting of 10 mm dia mild steel or deformed bars at 150 mm spacing which shall also extend up to a height of liner.

1206 WELL STEINING

1206.1 The dimensions, shape, concrete strength and reinforcements of the well shall strictly conform to those shown on the drawings. The formwork shall preferably be of M.S. sheets shaped and stiffened suitably. In case timber forms are used, they shall be lined with plywood or M.S. sheets.

1206.2 Steining built in the first lift above the well curb shall not be more than 2 m and in subsequent lifts it shall not exceed the diameter of the well or the depth of well sunk below the adjoining bed level at any time. For stability, the first lift of steining shall be cast only after sinking the curb at least partially for stability. Concreting of steining may be carried out in subsequent lifts of about 2 to 2.5 m. Attempts should be made to minimize the number of construction joints. The concreting layers shall be limited to 450 mm restricting the free fall of concrete to not more than 1.5 m. Laitance formed at the top surface of a lift shall be removed to expose coarse aggregates before setting of concrete at the proposed construction joint. As far as possible, construction joints shall not be kept at the location of laps in the vertical steining bars.

1206.3 The steining of the well shall be built in one straight line from bottom to top such that if the well is titled, the next lift of steining will be aligned in the direction of the tilt. The work will be checked carefully with the aid of straight edges of lengths approved by the Engineer. Plumb bob or spirit level shall not be used for alignment. After sinking of a stage is complete, damaged portions if any, of steining at top of the previous stage shall be properly repaired before constructing the next stage.

1206.4 The height of steining shall be calibrated by making at least 4 gauges (preferably in traffic direction and in a direction normal to traffic direction) distributed equally on the outer periphery of the well each in the form of a 100 mm wide strip painted on the well, with every metre mark shown in black paint. The gauges shall start with zero at the bottom of the cutting edge. Marking of the gauges shall be done carefully with a steel tape.

1206.5 After reaching the founding level, the well steining shall be inspected to check for any damage or cracks. The Engineer will direct and the Contractor shall execute

the remedial measures before acceptance of the well steining. In case the well cannot be accepted even with any remedial measure, then the well shall stand rejected.

1207 WELL SINKING

1207.1 General

The well shall as far as possible be sunk true and vertical through all types of strata.

Sinking or loading of the well with kentledge shall be commenced only after the steining has been cured for at least 48 hours or as specified in the drawings.

No well shall be permitted to be placed in a pre-dredged hole.

The well shall be sunk by excavating material uniformly from inside the dredge hole. Use of water jetting, explosives and divers may be adopted for sinking of wells through difficult strata with prior approval of the Engineer.

Normally dewatering of well should not be permitted as a means for sinking the well. It shall never be resorted to if there is any danger of sand blowing under the well. Dewatering shall however be done when well is to be founded into rock. Pneumatic sinking may have to be resorted to where obstacles such as tree trunks, large size boulders, etc. are met at the bottom or when there is hard strata which cannot be removed by open dredging. The necessity for pneumatic sinking shall be decided by the Engineer.

Sinking history of well shall be maintained in the format given in *Appendix* 1200/I.

1207.1.1 Sand blows in wells

Dewatering shall be avoided, if sand blows are expected. Any equipment or men working inside the well shall be brought outside the well as soon as there are any indications of sand blow. Sand blow often can be minimized by keeping the level of water inside the well higher than the water table and also by adding heavy kentledge**.**

1207.2 Use of Kentledge as Sinking Load

Kentledge shall be placed in an orderly and safe manner on the loading platform and in such a way that it does not interfere with the excavation of the material from inside the dredge hole and also does not in any way damage the steining of the well.

Where tilts are present or there is a danger of well developing a tilt, the position of the load shall be regulated in such a manner as to provide greater sinking effort on the higher side of the well.

1207.3 Use of Water Jetting

Water jetting and jack down method may be employed for well sinking as per requirement.

1207.4 Use of Explosives

Mild explosive charges may be used as an aid for sinking of the well only with prior permission of the Engineer. Blasting of any sort shall only be done in the presence of the Engineer and not before the concrete in the steining has hardened sufficiently and is more than 7 days old. When likelihood of blasting is predicted in advance, protection of the bottom portion of the well shall be done as per these Specifications.

After blasting operations are completed, the well curb and steining should be examined for any cracks and remedial measures taken.

If blasting has been used after the well has reached the design foundation level, normally 24 hours shall be allowed to lapse before the bottom plug is laid.

The charges shall be exploded well below the cutting edge by making a sump so as to avoid chances of any damage to the curb or to the steining of the well. A minimum sump of 1 m depth should be made before resorting to blasting. Use of large charges, 0.7 kg or above, may not be allowed except under expert direction and with the permissions from the Engineer. Suitable pattern of charges may be arranged with delay detonators to reduce the number of charges fired at a time. The burden of the charge may be limited to 1 m and the spacing of holes may normally be kept as 0.5 to 0.6 m.

All prevalent laws concerning handling, storing and using of explosives shall be strictly followed.

All safety precautions shall be taken as per IS:4081 “Safety Code for Blasting and related Drilling Operations”, to the extent applicable, whenever blasting is resorted to.

There should be no equipment inside the well nor shall there be any worker in the closed vicinity of the well at the time of exploding the charges.

If rock blasting is to be done for seating of the well, the damage caused by flying debris should be minimised by covering blasting holes by rubber mats before blasting.

1207.5 Use of Divers

Use of divers may be made both for the sinking purpose like removal of obstructions, rock blasting and for inspection. All safety precautions shall be taken as per any acceptable safety code for sinking with divers or any statutory regulations in force.

Only persons trained in the diving operation shall be employed and shall be certified to be fit for diving by an approved doctor.

They shall work under expert supervision. The diving and other equipments shall be of acceptable standard and certified to this effect by an approved independent agency. It shall be well maintained for safe use.

Arrangement for ample supply of low pressure clean cool air shall be ensured through an armoured flexible hose pipe. Standby compressor plant shall be provided in case of breakdown.

Separate high pressure connection for use of pneumatic tools shall be made. Electric lights where provided shall be at 50 volts (maximum). The raising of the diver from the bottom of wells shall be controlled so that decompression rate conforms to the rate as laid down in appropriate regulations.

1207.6 Use of Pneumatic Sinking

1207.6.1 General

The Engineer shall familiarize himself with particular reference to caisson diseases and working of the medical air-lock. A doctor competent to deal with cases of "Caisson Diseases" or other complications arising as a result of working under high pressure, shall be stationed at the construction site when pneumatic sinking is under progress.

The contractor shall provide complete facilities including the issuing of orders to ensure strict enforcement of the requirements outlined in these Specifications.

Safely provisions as contained in IS:4138 and in these Specifications shall be strictly followed.

Pneumatic sinking shall be restricted to a depth of 30.0 m.

1207.6.2 Man-Locks and Shafts

Locks, reducers, and shaft used in connection with caissons shall be of riveted construction throughout. The material used in their manufacture shall be steel plate with thickness not less than 6 mm.

Shafts shall be subjected to hydrostatic or air pressure test of at least 0.5 MPa, at which pressure they shall be tight. The pressure at which testing has been done shall be clearly and visibly displayed.

Shaft shall be provided, with a safe, proper and suitable staircase for its entire length including landing platforms which are not more than 6 m apart. Where this is impracticable due to space constraint, suitable ladders along with landing platforms shall be installed. These shall be kept clear and in good condition at all times and shall be constructed, inspected and maintained to the entire satisfaction of the Engineer.

A 1.0 m wide platform with 1.0 m high railing shall be provided all round the caisson air locks.

Where 15 or more men are employed, caissons shall have two locks, one of which shall be used as a man lock.

Locks shall be located so that the lowest part of the bottom door shall not be less than 1 m above high water level.

The supply of fresh air to the working chamber shall at all times be sufficient to permit work to be done without any danger or excessive discomfort. All air supply lines shall be supplied with check valves and carried as near to the face as practicable.

A man-lock shall be used solely for the compression or de-compression of persons, and not for the passage of plant and material and shall be maintained in a reasonably clean and sufficiently warm state. However, any hand tool or hand instruments used for the purpose of the work may be carried into the man-lock.

Where is it not reasonably practicable to provide a separate man-lock for use by persons only, the lock when it is in actual use for compression or decompression of a person or persons shall not be put, simultaneously, to any other use and shall be in a reasonably clean and sufficiently warm state.

1207.6.3 Valves

Exhaust valves shall be provided, having risers extending to the upper part of the chamber. These shall be operated, whenever necessary specially after a blast. Precautions shall be taken that men are not allowed to resume work after a blast until the gas and smoke are cleared.

1207.6.4 Medical supervision and certification

Every employee absent from work for 10 or more consecutive days due to illness or any other disability shall be required to pass the regular physical examination by the doctor before being permitted to return to work.

After a person has been employed continuously in compressed air for a period of 2 months,

he shall be re-examined by the doctor and shall not be permitted to work until such re-examination has been made and the repot is satisfactory.

No person known to be addicted to the excessive use of intoxicants shall be permitted to work in compressed air.

The doctor shall, at all times, keep a complete and full record of examination made by him, which shall contain dates of examinations, a clear and full description of the persons examined, his age and physical condition at the time of examination and a statement as to the period such a person has been engaged in such employment. Records shall be kept at the place where the work is in progress and shall be subject to inspection by authorized officers.

Every man lock shall always have a doctor or a responsible person in attendance. In case the person in charge is not a doctor, he must have positive means of promptly communicating with and securing the services of a competent doctor in case of emergency. Such arrangements shall invariably be subject to the approval of the Engineer.

If the air pressure exceeds 0.2 MPa gauge or if 50 or more men are employed, it is obligatory for the person in charge of medical lock to be a doctor experienced in this type of work.

All cases of compressed-air illness shall be reported and copies of all such reports shall be kept in file at the place of work.

1207.6.5 Lighting

All lighting in compressed air chambers shall be operated only by electricity. Two independent electric lighting systems with independent sources of supply shall be used. These shall be so arranged that the emergency source shall become automatically operative in case of failure of the regularly used source.

The minimum intensity of light on any walkway ladder, stairway, or lower working level shall be one-quarter (1/4) candlepower. In all work places, the lighting shall always be such as to enable workmen to see their way about clearly. All external parts of lighting fixtures and electrical equipment lying with in 2.5 m above the floor shall be constructed of non-combustible, non-absorbing insulating materials. If metal is used it must be effectively earthed. Portable lamp shall have non-combustible, non-absorbing insulating sockets, approved handles, basket guards and approved cables. The use of worn out or defective portable and pendant conductors, shall be prohibited.

1207.6.6 Safety against fire hazard

No oil, gasoline, or other combustible material shall be stored within 30 m of any shaft, caisson, or tunnel opening. However, oil may be stored in suitable tanks in isolated fireproof buildings, provided such buildings are not less than 15 m from any shaft, caisson, or tunnel opening or any building directly connected thereto.

Positive means shall be taken to prevent leaking flammable liquids from flowing into areas specifically mentioned in the preceding paragraph.

Where feasible, a fire hose connected to a suitable source of water shall be provided at the top of every caisson. Where fire mains are not accessible, water shall be stored in tanks near the top of every caisson, provided fire pails or suitable pumps are kept available. Approved fire extinguishers shall also be provided.

1207.6.7 Sanitation

Properly heated, lighted and ventilated dressing rooms shall be provided for all employees engaged in compressed air work. Such rooms shall contain lockers and benches and be open and accessible to person during intermissions between shifts. Adequate toilet accommodation of one for every twenty five employees shall be provided.

Care shall be taken to keep all parts of the caissons and other working compartments, including locker rooms, dry rooms, rest rooms, and other equipments in a good sanitary condition and free from refuse, decaying or other objectionable matter.

No nuisance shall be tolerated in the air chamber. Smoking shall be strictly prohibited and all matches and smoking materials shall be left out of the locker rooms.

A separate dry-room shall be provided where working clothes may be dried in a reasonable time.

1207.6.8 Protection against gases

In all cases where gas is expected including alluvium impregnated with decayed vegetable matter, the use of Davy Safety Lamp shall be compulsory.

1207.6.9 Additional safety provisions

a) The weight of the pneumatic platform and that of steining and kentlege, if any, shall be sufficient to resist the uplift from air inside, skin friction being neglected in this case, If, at any section the total weight acting downwards is less than the uplift pressure of air inside, additional kentledge shall be placed on the well.

If it is not possible to make the well heavy enough during excavation, "blowing down" may be used. The men should be withdrawn and air pressure reduced. The well should then begin to move with small reduction in air pressure. "Blowing down" should only be used when the ground is such that it will not heave up inside the chamber when the pressure is reduced. When the well does not move with the reduction in air pressure, kentledge should be added. "Blowing down" should be in short stages and the drop should not exceed, 0.5 m at any stage. To control sinking during blowing down use of packing are recommended.

b) The pneumatic sinking plant and other allied machinery shall not only be of proper design and make, but also shall be operated by competent and well trained personnel. Every part of the machinery and its fixtures shall be minutely examined before installation and use. Availability of appropriate spares, standbys, safety of personnel as recommended in IS:4138 for working in compressed air must be ensured at site. Codes for safety and for working in compressed air and other labour laws and practices prevalent in the country, as specified to provide safe, efficient and expeditious sinking shall be followed.

c) Inflammable materials shall not be taken into air locks and smoking shall be prohibited. Wherever gases are suspected to be issuing out of dredge hole, the same shall be analysed by trained personnel and necessary precautions adopted to avoid hazard to life and equipment.

d) Where blasting is resorted to, it shall be carefully controlled and all precautions regarding blasting shall be observed. Workers shall be allowed inside after blasting only when a competent and qualified person has examined the chamber and steining thoroughly, and found the same to be safe.

1207.7 Precautions during sinking

a) When the wells have to be sunk close to each other and clear distance between them is not greater than the diameter of wells, sinking shall be taken up on all wells and they shall be sunk alternately so that sinking of wells proceeds uniformly. Simultaneous and even dredging shall be carried out in the wells in such a manner that the difference in the levels of the sump and cutting edge in the adjacent wells does not exceed half the clear gap between them. Plugging of all the wells shall be done together.

b) During sinking of dumb-bell or double D-shaped wells, the excavation in both the dredge holes should be carried out simultaneously and equally.

c) Bore chart shall be referred to constantly during sinking for taking adequate care while piercing different types of strata. The type of soil as obtained during the well sinking should be compared with bore chart so as to take prompt decisions.

d) Before seasonal floods, all wells on which sinking is in progress shall be sunk to sufficient depths below the designed scour level. Further, they shall be temporarily filled and plugged so that they do not suffer any tilt or shift during the floods.

e) All necessary precautions shall be taken against any possible damage to the foundations of existing structures in the vicinity of the wells, prior to commencement of dredging from inside the well.

f) The dredged material shall not be allowed to accumulate over the well. It shall be dumped and spread, as far away as possible, and then continuously and simultaneously removed, as directed by the Engineer. In case the river stream flows along one edge of the well being sunk, the dredged material shall not be dumped on the dry side of the bank but on the side on which the river current flows.

g) Very deep sump shall not be made below the well curb, as it entails risk of jumping (sudden sinking) of the well. The depth of sump shall be generally limited to one-sixth of the outer diameter/least lateral dimension of the well in plan. Normally the depth of sump shall not exceed 3.0 m below the level of the cutting edge unless otherwise specially permitted by the Engineer.

h) In case a well sinks suddenly with a jerk, the steining of the well shall be examined to the satisfaction of the Engineer to see that no damage has occurred to it.

i) In pneumatic sinking, the well shall not, at any time, be dropped to a depth greater than 500 mm by the method of “blowing down”.

j) Dewatering shall be avoided if sand blows are expected. Any equipment and men working inside the well shall be brought out of the well as soon as there are any indications of a sand-blow.

k) Sand blowing in wells can often be minimised by keeping the level of water inside the well higher than the water table and also by adding heavy kentledge.

l) In soft strata prone to settlement/creep, the construction of the abutment wells shall be taken up only after the approach embankment for a sufficient distance near the abutment has been completed.

1207.8 Tilts and Shifts

The inclination of the well from the vertical is known as tilt and the horizontal displacement of the center of the well at the founding level from its theoretical position is known as shift.

Unless otherwise specified, the tilt of any well shall not exceed 1 (horizontal) in 80 (vertical), and the shift at the well base shall not be more than 150 mm in any resultant direction.

Tilts and shifts shall be carefully checked and recorded in the format vide *Appendix 1200/II* regularly during sinking operations. For the purpose of measuring the tilts along the two axes of the bridge, reduced level of the marks painted on the surface of the steining of the well shall be taken. For determination of shift, locations of the ends of the two diameters shall be precisely measured along the two axes, with reference to fixed reference points.

Whenever any tilt is noticed, adequate preventive measures like placing eccentric kentledge, pulling, strutting, anchoring or dredging unevenly and depositing dredge material unequally, putting obstacles below cutting edge. Water jetting etc., shall be adopted before any further sinking. After correction, the dredged material shall be spread out uniformly.

A pair of wells close to each other have a tendency to come closer while sinking. Timber struts may be introduced in between the steining of these wells to prevent tilting.

Tilts occurring in a well during sinking in dipping rocky strata can be safeguarded by suitably supporting the curb.

In the event of a well developing tilt or shift beyond the specified permissible values, the Contractor shall have to carry out, at his own cost, suitable remedial measures to the satisfaction of the Engineer, to bring the tilt and shift within permissible values.

If the resultant tilt and / or shift of any well exceeds the specified permissible values, generally it should not exceed 1 in 50 and 300 mm respectively. The well so sunk shall be regarded as not conforming to specifications and a sub-standard work. The Engineer in his sole discretion, may consider accepting such a well, provided:

i) Calculations for foundation pressures and steining stresses, accounting for the actual tilt and shift furnished by the Contractor show that the well is safe. Remedial measures required to bring the stresses within permissible values (such as increase in the dimension of the

well cap, provision of dummy weights on the well cap etc.), shall be carried out by the Contractor at his own cost.

ii) The Contractor shall be subjected to reduction in rates as a penalty in accordance with Clause 1215(g).

In case the Engineer, in his discretion, rejects the well, the Contractor shall dismantle the rejected well to the extent directed by the Engineer and remove the debris. Further, the Contractor shall, at his own risk and cost complete the bridge with modified span arrangement acceptable to the Engineer.

1207.9 Floating caissons

Floating caissons may be of steel, reinforced concrete or any suitable material. They shall have at least 1.5 m free board above the water level and increased, if considered necessary, in case there is a possibility of caissons sinking suddenly owing to reasons, such as scour likely to result from lowering of caissons, effect of waves, sinking in very soft strata, etc.

Well caissons should be checked for stability against over-turning and capsizing while being towed and during sinking, due to the action of water current, wave pressure, wind etc.

The floating caisson shall not be considered as part of foundation unless proper shear transfer at the interface is ensured.

1207.10 Seating of Wells

The well shall be uniformly seated at the founding strata. It shall be ensured by test borings that the properties of the soil encountered at the founding strata and upto a depth of one and a half times the well diameter is identical to that adopted in the design. The procedure for test borings shall satisfy the provisions of these specifications. In case the soil encountered is inferior to that adopted in design, the well shall be re-designed by the Engineer adopting the soil properties actually encountered and the founding level intimated to the Contractor, who shall carry out the work accordingly.

In case of seating of wells in hard rocky strata, where the rock profile is steeply sloping, pneumatic methods of sinking may be adopted to seat the well evenly as directed by the Engineer. The decision of adopting pneumatic sinking shall be taken by the Engineer. The cutting edge may also be embedded for a suitable depth in the rocky strata, as decided by the Engineer keeping in view the quality of rock. As an additional measure of safety, the well shall be anchored to the rocky strata by anchor bars provided in the steining of the well, as shown on the drawing irrespective of the fact that tension develops or not at the base of the well under design loads. After the well has been evenly seated on good hard rock, arrangements shall be made to facilitate proper inspection in dry and visible conditions before the bottom plug is laid.

1208 BOTTOM PLUG

The bottom plug shall be provided in all wells and the top shall be kept not lower than 300 mm in the centre above the top of the curb, as shown in *Appendix-3* of IRC:78. A suitable sump shall be below the level of the cutting edge. Before concreting the bottom plug, it shall be ensured that its inside faces have been cleaned thoroughly.

The concrete mix used in bottom plug shall have a minimum cement content of 330 kg per cu.m with a slump about 150 mm to permit easy flow of concrete through tremie to fill-up all cavities. Concrete shall be laid in one continuous operation till the dredge hole is filled to the required height. For under water concrete, the concrete shall be placed by tremie under still water condition and the cement content of the mix be increased by 10 percent. Admixtures, if required may be added to the concrete to achieve the required characteristics.

In case of grouted concrete, the grout mix shall not be leaner than 1:2. It shall be ensured that the grout fills up all interstices upto the top of the bottom plug by suitable means such as, controlling the rate of pumping etc.

Any dewatering required, shall be done 14 days after concreting of bottom plug.

The concrete production equipment and placement equipment should be sufficient to enable under water concreting within stipulated time. Necessary standby equipment should be available for emergency situation.

Before commencing plugging, all loose material from the bottom of the well shall be removed.

Concreting shall be done in one continuous operation till the dredge hole is filled upto the required height and thereafter sounding shall be taken up to ensure that the concrete has been laid to the required height.

Least disturbance shall be caused to the water inside the well while laying concrete in the bottom plug.

Concrete shall not be disturbed in any way for at least 14 days.

In order to check any rise in the level of the bottom plug soundings should be taken at the close of concreting and once every day for the subsequent 3 days.

The soundness of the bottom plug may be tested by dewatering the well by 5 m below the surrounding water level and checking the rise of water. The rate of rise shall preferably be less than 10 cm per hour. In case the rate is higher, suitable remedial measures as directed by the Engineer, shall be taken by the Contractor at his own cost.

1209 SAND FILLING

Sand filling shall commence after a period of 14 days of laying of bottom plug. Also, the height of the bottom plug shall be verified before starting sand filling.

Sand shall be clean and free from earth, clay clods, roots, boulders, shingles, etc. and shall be compacted as directed. Sand filling shall be carried out upto the level shown on the drawing or as directed by the Engineer.

1210 TOP PLUG

After filling sand upto the required level a plug of 300 mm thick concrete shall be provided over it as shown on the drawing or as directed by the Engineer.

1211 WELL CAP

A reinforced cement concrete well cap will be provided over the top of the steining in accordance with the drawing. Formwork will be prepared conforming to the shape of well cap. Concreting shall be carried out in dry condition. A properly designed false steining may be provided where possible to ensure that the well cap is laid in dry condition.

The bottom of the well cap shall be laid preferably as low as possible but not below the LWL, taking in to account for this purpose, the water level prevalent at the time of casting Where the bed level is higher than the LWL, the bottom of the well cap may be suitably raised.

Bond rods of steining shall be anchored into the well cap.

1212 TOLERANCES

The permissible tilt and shift shall not exceed 1 (horizontal) in 80 (vertical) and the shift at the well base shall not be more than 150 mm in any resultant direction.

For the well steining and well cap, the permissible tolerances shall be as follows:

a)	Variation in dimension	:	+50 mm, –10 mm
b)	Misplacement from specified position in plan	:	15 mm
c)	Surface irregularities measured with 3 m straight edge	:	5 mm
d)	Variation of level at the top	:	$\pm$ 25 mm

1213 TESTS AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

1214 MEASUREMENTS FOR PAYMENT

All quantities shall be measured from the drawing, or as ordered by the Engineer, excepting those required to be provided by the Contractor at his cost.

a) The cutting edge shall be measured in tonnes based on the net weight of metal used in it, as per Section 1900.

b) The concrete in curb, well steining and well cap shall be measured in cubic metres in each of the items as per Section 1700. The reinforcements shall be measured in tonnes separately in each of the items, as per Section 1600.

c) The measurement for well sinking shall be made in running metres for different depths and in different types of strata (for example, predominantly sand/clay soil, soft rock, hard rock, etc.) as specified in the Contract. The depth of sinking shall be measured from the level specified in the Contract. If no level has been specified in the Contract, sinking shall be measured from the low water level or from the level at which the cutting edge was laid, whichever is higher.

d) The quantity of concrete in bottom and top plug shall be measured in cubic metres as per Section 1700.

e) The quantity of sand filling shall be measured in cubic metres.

f) Pneumatic sinking, where required shall be paid as a separate item and shall be measured in cubic metres of material to be excavated.

1215 RATE

All quantities shall be measured from the drawing or as ordered by the Engineer, excepting those required to be provided by the Contractor at his cost.

a) The Contract unit rates of cutting edge shall cover all costs of labour, material, tools, plant and equipment, including placing in position, sampling and testing, and, supervision, all as per respective Section of Structural Steel Work and as described in this section.

b) The Contract unit rates for concrete in curb, steining, bottom plug, top plug and well cap, shall cover all costs of labour, material, tools, plant and equipment, formwork and staging including placing in position, sampling and testing, and, supervision, all as per respective Section of Structural Concrete and as described in this section.

c) The Contract unit rates for reinforcement in curb, steining, and well cap, shall cover all costs of labour, material, tools, plant and equipment, including bending to shape, placing in position, sampling, testing and supervision, all as per respective Section of Steel Reinforcement and as described in this section.

d) The Contract unit rates for sand filling shall cover all costs of labour, material, tools, plant and equipment, including placing in position, sampling testing and supervision, all as described in this section.

e) The Concrete unit rates for sinking shall cover the costs of labour, tools, and equipment and plant and for all operations and other incidentals for sinking of well including seating excepting provisions of pneumatic sinking as described in this Section. The unit rates shall specify the strata such as types of soil, rock, etc. The rate shall cover all testing and supervision required for the work.

f) The Contract unit rate of material to be excavated by pneumatic sinking shall cover all costs of labour, material, tools, plant and other equipment and other incidentals and safety provisions and supervision required for pneumatic sinking as per this Section.

g) Reduction in contract unit rates for sinking as a penalty, in pursuance of Clause 1207.8

If any well with tilt and/or shift exceeding the permissible values is accepted by the Engineer, the Contractor shall be subjected to a reduction in the rates as follows:

S.No.	**Amount of tilt and/or shift**	**Per cent deduction on the rate (s) for sinking of whole well**
1.	Tilt exceeding the specified permissible value but equal to or within 1 in 60	5 percent
2.	Tilt exceeding 1 in 60 but equal to or within 1 in 50	10 percent
3.	Tilt exceeding 1 in 50	20 percent
4.	Shift exceeding the specified permissible value but equal to or within 200 mm	2 percent
5.	Shift exceeding 200 mm but equal to or within 300 mm	5 percent
6.	Shift exceeding 300 mm	10 percent

Rates for excessive tilt and shift shall be reduced separately.

1300

Brick Masonry

1301 DESCRIPTION

This work shall consist of construction of structures with bricks jointed together by cement mortar in accordance with the details shown on the drawings or as approved by the Engineer.

1302 MATERIALS

All materials to be used in the work shall conform to the requirements laid down in Section 1000.

1303 PERSONNEL

Only trained personnel shall be employed for construction and supervision.

1304 CEMENT MORTAR

Cement and sand shall be mixed in specified proportions given in the drawings. Cement shall be proportioned by weight, taking the unit weight of cement as 1.44 tonne per cubic metre. Sand shall be proportioned by volume taking into account due allowance for bulking. All mortar shall be mixed with a minimum quantity of water to produce desired workability consistent with maximum density of mortar. The mix shall be clean and free from injurious type of soil/acid/alkali/organic matter or deleterious substances.

The mixing shall preferably be done in a mechanical mixer operated manually or by power. Hand mixing can be resorted to as long as uniform density of the mix and its strength are assured subject to prior approval of the Engineer. Where permitted, specific permission is to be given by the Engineer. Hand mixing operation shall be carried out on a clean water-tight platform, where cement and sand shall be first mixed dry in the required proportion by being turned over and over, backwards and forwards several times till the mixture is of uniform colour. Thereafter, minimum quantity of water shall be added to bring the mortar to the consistency of a stiff paste. The mortar shall be mixed for at least two minutes after addition of water.

Mortar shall be mixed only in such quantity as required for immediate use. The mix which has developed initial set shall not be used. Initial set of mortar with ordinary Portland Cement shall normally be considered to have taken place in 30 minutes after mixing. In case the mortar has stiffened during initial setting time because of evaporation of water, the same can be re-tempered by adding water as frequently as needed to restore the requisite consistency, but this re-tempering shall not be permitted after 30 minutes. Mortar unused for more than 30 minutes shall be rejected and removed from site of work.

1305 SOAKING OF BRICKS

All bricks shall be thoroughly soaked in a tank filled with water for a minimum period of one hour prior to being laid. Soaked bricks shall be removed from the tank sufficiently in advance so that they are skin dry at the time of actual laying. Such soaked bricks shall be stacked on a clean place where they are not contaminated with dirt, earth, etc.

1306 JOINTS

The thickness of joints shall not exceed 10 mm. All joints on exposed faces shall be tooled to give concave finish.

1307 LAYING

All brickwork shall be laid in an English bond, even and true to line, in accordance with the drawing or as directed by the Engineer, plumb and level and all joints accurately kept. Half and cut bricks shall not be used except when necessary to complete the bond. Closer in such cases shall be cut to the required size and used near the ends of the walls. The bricks used at the face and also at all angles forming the junction of any two walls shall be selected whole bricks of uniform size, with true and rectangular faces.

All bricks shall be laid with frogs up on a full bed of mortar except in the case of tile bricks. Each brick shall be properly bedded and set in position by slightly pressing while laying, so that the mortar gets into all their surface pores to ensure proper adhesion. All head and side joints shall be completely filled by applying sufficient mortar to brick already placed and on brick to be placed. All joints shall be properly flushed and packed with mortar so that no hollow spaces are left. No bats or cut bricks shall be used except to obtain dimensions of the different courses for specified bonds or wherever a desired shape so requires.

The brick work shall be built in uniform layers, and for this purpose wooden straight edge with graduations indicating thickness of each course including joint shall be used. Corners and other advanced work shall be raked back. Brickwork shall be done true to plumb or in specified batter. All courses shall be laid truly horizontal, and vertical joints shall be truly vertical. Vertical joints in alternate courses shall come directly one over the other. During construction, no part of work shall rise more than one metre above the general construction level, to avoid unequal settlement and improper jointing. Where this is not possible in the opinion of the Engineer, the works shall be raked back according to the bond (and not toothed) at an angle not steeper than 45 degrees with prior approval of the Engineer. Toothing may also be permitted where future extension is contemplated.

Before laying bricks in foundation, the foundation slab shall be thoroughly hacked, swept clean and wetted. A layer of mortar not less than 12 mm thick shall be spread on the surface of the foundation slab and the first course of bricks shall be laid.

1308 JOINTING OLD AND NEW WORK

Where fresh masonry is to joint with masonry that is partially/entirely set, the exposed jointing surface of the set masonry shall be cleaned, roughened and wetted, so as to effect the best possible bond with the new work. All loose bricks and mortar or other material shall be removed.

In the case of vertical or inclined joints, it shall be further ensured that proper bond between the old and new masonry is obtained by interlocking the bricks. Any portion of the brickwork that has been completed shall remain undisturbed until thoroughly set.

In case of sharp corners specially in skew bridges, a flat cutback of 100 mm shall be provided so as to have proper and bonded laying of bricks.

1309 CURING

Green work shall be protected from rain by suitable covering and shall be kept constantly moist on all faces for a minimum period of seven days. Brick work carried out during the day shall be suitably marked indicating the date on which the work is done so as to keep a watch on the curing period. The top of the masonry work shall be left flooded with water at the close of the day. Watering may be done carefully so as not to disturb or wash out the green mortar.

During hot weather, all finished or partly completed work shall be covered or wetted in such a manner as will prevent rapid drying of the brickwork.

During the period of curing of brick work, it shall be suitably protected from all damages. At the close of day's work or for other period of cessation, watering and curing shall have to be maintained. Should the mortar perish i.e. become dry, white or powdery through neglect of curing, work shall be pulled down and rebuilt as directed by the Engineer. If any stains appear during watering, the same shall be removed from the face.

1310 SCAFFOLDING

The scaffolding shall be sound, strong and safe to withstand all loads likely to come upon it. The holes which provide resting space for horizontal members shall not be left in masonry under one metre in width or immediately near the skew backs of arches. The holes left in the masonry work for supporting the scaffolding shall be filled and made good. Scaffolding shall be got approved by the Engineer. However, the Contractor shall be responsible for its safety.

1311 EQUIPMENT

All tools and equipment used for mixing, transporting and laying of mortar and bricks shall be clean and free from set mortar, dirt or other injurious foreign substances.

1312 FINISHING OF SURFACES

1312.1 General

All brickwork shall be finished in a workmanlike manner with the thickness of joints, manner of striking or tooling as described in these Specifications.

The surfaces can be finished by “jointing” or “pointing” or by “plastering” as given in the drawings.

For a surface which is to be subsequently plastered or pointed, the joints shall be squarely raked out to a depth of 15 mm, while the mortar is still green. The raked joints shall be well brushed to remove dust and loose particles and the surface shall be thoroughly washed with water, cleaned and wetted.

The mortar for finishing shall be prepared as per Clause 1304.

1312.2 Jointing

In jointing, the face of the mortar shall be worked out while still green to give a finished surface flush with the face of the brick work. The faces of brick work shall be cleaned to remove any splashes of mortar during the course of raising the brick work.

1312.3 Pointing

Pointing shall be carried out using mortar not leaner than 1:3 by volume of cement and sand or as shown on the drawing. The mortar shall be filled and pressed into the raked joints before giving the required finish. The pointing shall be ruled type for which it shall, while still green, be ruled along the center with half round tools of such width as may be specified by the Engineer. The super flush mortar shall then be taken off from the edges of the lines and the surface of the masonry shall be cleaned of all mortar. The work shall conform to IS:2212.

1312.4 Plastering

Plastering shall be done where shown on the drawing. Superficial plastering may be done, if necessary, only in structures situated in fast flowing rivers or in severely aggressive environment.

Plastering shall be started from top and worked down. All putlog holes shall be properly filled in advance of the plastering while the scaffolding is being taken down. Wooden screeds 75 mm wide and of the thickness of the plaster shall be fixed vertically 2.5 to 4 m apart, to act as gauges and guides in applying the plaster. The mortar shall be laid on the

wall between the screeds using the plaster's float and pressing the mortar so that the raked joints are properly filled. The plaster shall then be finished off with a wooden straight edge reaching across the screeds. The straight edge shall be worked on the screeds with a small upward and sideways motion 50 mm to 75 mm at a time. Finally, the surface shall be finished off with a plaster's wooden float. Metal floats shall not be used.

When recommencing the plastering beyond the work suspended earlier, the edges of the old plaster shall be scrapped, cleaned and wetted before plaster is applied to the adjacent areas.

No portion of the surface shall be left unfinished for patching up at a later period.

The plaster shall be finished true to plumb surface and to the proper degree of smoothness as directed the Engineer.

The average thickness of plaster shall not be less than the specified thickness. The minimum thickness over any portion of the surface shall not be less than the specified thickness by more than 3 mm.

Any cracks which appear in the surface and all portions which sound hollow when tapped, or are found to be soft or otherwise defective, shall be cut in rectangular shape and re-done as directed the Engineer.

1312.5 Curing of Finishes

Curing shall be commenced as soon as the mortar used for finishing has hardened sufficiently not to be damaged during curing. It shall be kept wet for a period of at least 7 days. During this period, it shall be suitably protected from all damages.

1312.6 Scaffolding for Finishes

State scaffolding shall be provided for the work. This shall be independent of the structure.

1313 ARCHITECTURAL COPING FOR WING/RETURN/PARAPET WALL

This work shall consist of providing an architectural coping for wing/return/parapet walls.

The material used shall be cement mortar 1:3 or as shown on the drawings prepared in accordance with Clause 1304.

The cement mortar shall be laid evenly to an average thickness of 15 mm to the full width of the top of the wall and in continuation a band of 15 mm thickness and 150 mm depth shall be made out of the mortar along the top outer face of the walls.

1314 ACCEPTANCE OF WORK

All work shall be true to the lines and levels as indicated on the drawing or as directed by the Engineer, subject to tolerances as indicated in these Specifications.

Mortar cubes shall be tested in accordance with IS:2250 for compressive strength, consistency of mortar and its water retentivity. The frequency of testing shall be one sample for every 2 cubic metres of mortar subject to a minimum 3 samples for a day's work.

In case of plaster finish, the minimum surface thickness shall not be less than the specified thickness by more than 3 mm.

1315 MEASUREMENTS FOR PAYMENT

1315.1 All brick work shall be measured in cubic metres. Any extra work done by the Contractor over the specified dimensions shall be ignored.

1315.2 In arches, the length of arch shall be measured as the mean length between the extrados and intrados.

1315.3 The work of plastering and pointing shall be measured in square metres of the surface treated.

1315.4 Architectural coping shall be measured in linear metres.

1316 RATE

1316.1 The contract unit rate for brick work shall include the cost of all labour, materials, tools and plant, scaffolding and other expenses incidental to the satisfactory completion of the work, sampling, testing and supervision as described in these Specifications and as shown on the drawings.

1316.2 The contract unit rate for plastering shall include the cost of the labour, materials, tools and plant, scaffolding and all incidental expenses, sampling and testing and supervision as described in these Specifications.

1316.3 The contract unit rate for pointing shall include erecting and removal of scaffolding, all labour, materials, and equipment incidental to complete the pointing, raking out joints, cleaning, wetting, filling with mortar, trowelling, pointing and watering, sampling and testing and supervision as described in these Specifications.

1316.4 The contract unit rate for architectural coping shall include cost of all labour, materials, tools and plant, sampling and testing and supervision as described in these Specifications.

1400

Stone Masonry

1401 DESCRIPTION

This work shall consist of construction of structures with stones jointed together by cement mortar in accordance with the details shown on the drawings and these Specifications or as approved by the Engineer.

1402 MATERIALS

All materials to be used in stone masonry shall conform to Section 1000 except cement mortar for stone masonry which shall conform to Clause 1304.

1403 PERSONNEL

Only trained personnel shall be employed for construction and supervision.

1404 TYPE OF MASONRY

The type of masonry used for structures shall be random masonry (coursed or uncoursed) or coursed rubble masonry (First sort). However, for bridge work generally, course rubble stone masonry shall be used. The actual type of masonry used for different parts of structures shall be specified on the drawings. For facing work, ashlar masonry shall be used where indicated on the drawings.

1405 CONSTRUCTION OPERATIONS

1405.1 General Requirements

The dressing of stone shall be as specified for individual type masonry work and it shall also conform to the general requirements of IS:1597 and requirement for dressing of stone covered in IS:1129. Other specific requirements are covered separately with respect to particular types of rubble stone work.

1405.2 Laying

1405.2.1 The masonry work shall be laid to lines, levels, curves and shapes as shown in the plan. The height in each course shall be kept same and every stone shall be fine tooled on all beds joints and face full and true. The exposed faces shall be gauged out, grooved, regulated and sunk or plain moulded as the case may be. The faces of each stone between the draft be left rough as the stone comes from quarry except where sacrificial layer is to be provided or plastering is resorted to due to aggressive environment.

1405.2.2 Stones shall be sufficiently wetted before laying to prevent absorption of water from mortar.

Stratified stones must be laid on their natural beds. All bed joints shall be normal to the pressure upon them.

Stones in the hearting shall be laid on their broadest face that gives a better opportunity to fill the spaces between stones.

The courses of the masonry shall ordinarily be pre-determined. They shall generally be of the same height. When there is to be variation in the height of courses, the larger courses are to be placed at lower levels, heights of courses decreasing gradually towards the top of the wall. Placing loose mortar on the course and pouring water on it to fill the gaps in stones is not acceptable. Mortar may be fluid mixed thoroughly and then poured in the joints. No dry or hollow space shall be left anywhere in the masonry and each stone shall have all the embedded faces completely covered with mortar.

In tapered walls, the beds of the stones and the planes of course should be at right angles to the batter. In case of bridge piers with batter on both sides, the course shall be horizontal.

The bed which is to receive the stone shall be cleaned, wetted and covered with a layer of fresh mortar. All stones shall be laid full in mortar both in bed and vertical joints and settled carefully in place with a wooden mallet immediately on placement and solidly embedded in mortar before it has set. Clean chips and spalls shall be wedged into the mortar joints and bed wherever necessary to avoid thick beds or joints of mortar. When the foundation masonry is laid directly on rock, the face stones of the first course shall be dressed to fit into rock snugly when pressed down in the mortar bedding over the rock. No dry or hollow space shall be left anywhere in the masonry and each stone shall have all the embedded faces completely covered with mortar. For masonry works over rock, a levelling course of 100 mm thickness and in concrete M 15 shall be laid over rock and then stone masonry work shall be laid without foundation concrete block.

Face works and hearting shall be brought up evenly but the top of each course shall not be levelled up by the use of flat chips.

For sharp corners specially in skew bridges, through stones shall be used in order to avoid spalling of corners.

In case any stone already set in mortar is disturbed or the joints broken, it shall be taken out without disturbing the adjoining stones and joints. Dry mortar and stones thoroughly cleaned from the joints and stones and the stones reset in fresh mortar. Attempt must never be made to slide one stone on top of another, freshly laid.

Shaping and dressing shall be done before the stone is laid in the work. No dressing and hammering, which will loosen the masonry, will be allowed after it is once placed all necessary chases for joggles, dowels and clamps should be formed before hand.

Sufficient transverse bonds shall be provided by the use of bond stone extending from the front to the back of the wall and in case of thick wall from outside to the interior and vice versa. In the latter case, bond stones shall overlap each other in their arrangement.

In case headers shall not be available, precast headers of M 15 concrete shall be used. Cast-in-situ headers are not permitted.

Stones shall break joint on the face for at least half the height of the course and the bond shall be carefully maintained throughout.

In band work at all angle junctions of walls, the stones at each alternate course shall be carried into each of the respective walls so as to unite the work thoroughly.

Building up thin faces tied with occasional through stones and filling up the middle with small stuff or even dry packing is not acceptable.

All quoins and the angles of the opening shall be made from selected stones, carefully squared and bedded and arranged to bond alternately long and short in both directions.

All vertical joints shall be truly vertical. Vertical joints shall be staggered as far as possible. Distance between the nearer vertical joints of upper layer and lower shall not be less than half the height of the course.

Only rectangular shaped bond stones or headers shall be used. Bond stones shall overlap each other by 150 mm or more.

All connected masonry in a structure shall be carried up nearly at one uniform level throughout but when breaks are unavoidable, the masonry shall be raked in sufficiently long steps to facilitate jointing of old and new work. The stepping of raking shall not be more than 45 degrees with the horizontal.

1405.3 Random Masonry (Uncoursed and Coursed)

1405.3.1 Dressing : Stone shall be hammer dressed on the face, the sides and beds to enable it to come in proximity with the neighbouring stone. The bushing on the exposed face shall not be more than 40 mm.

1405.3.2 Insertion of chips : Chips and spalls of stone may be used wherever necessary to avoid thick mortar beds or joints and it shall be ensured that no hollow spaces are left anywhere in the masonry. The chips shall not be used below hearting stones to bring these upto the level of face stones. Use of chips shall be restricted to filling of interstices between the adjacent stones in hearting and they shall not exceed 20 per cent of the quantity of stone masonry.

1405.3.3 Hearting stones : The hearting or interior filling of the wall face shall consist of rubble stones not less than 150 mm in any direction, carefully laid, hammered down with a wooden mallet into position and solidly bedded in mortar. The hearting should be laid nearly level with facing and backing.

1405.3.4 Bond stones : Through bond stones shall be provided in masonry upto 600 mm thickness and in case of masonry above 600 mm thickness, a set of two or more bond stones overlapping each other at least by 150 mm shall be provided in a line from face to back. In case of highly absorbent types of stones (porous limestone and sandstones, etc.,) the bond stone shall extend only about two-thirds into the wall, as through stones in such cases may give rise to penetration of dampness and therefore, for all thicknesses of such masonry, a set of two or more bond stones overlapping each other by at least 150 mm shall be provided. One bond stone or a set of bond stones shall be provided for ever 0.50 sq.m of the masonry surface.

1405.3.5 Quoin stone : Quoin stone i.e. stone specially selected and neatly dressed for forming an external angle in masonry work, shall not be less than 0.03 cubic metre in volume.

1405.3.6 Plum stone : The plum stones are selected long stones embedded vertically in the interior of the masonry to form a bond between successive courses and shall be provided at about 900 mm intervals.

1405.3.7 Laying : The masonry shall be laid with or without courses as specified. The quoins shall be laid header and stretcher alternately. Every stone shall be fitted to the adjacent stone so as to form neat and close joint. Face stone shall extend and bond well in the back. These shall be arranged to break joints, as much as possible, and to avoid long vertical lines of joints.

1405.3.8 Joints : The face joints shall not be more than 20 mm thick, but shall be sufficiently thick to prevent stone-to-stone contact and shall be completely filled with mortar.

1405.4 Square Rubble : Coursed Rubble (First Sort)

1405.4.1 Dressing : Face stone shall be hammer dressed on all beds and joints so as to give them rectangular shape. These shall be square on all joints and beds. The bed joints shall be chisel drafted for at least 80 mm back from the face and for at least 40 mm for the side joints. No portion of the dressed surface shall show a depth of gap more than 6 mm from the straight edge placed on it. The remaining unexposed portion of the stone shall not project beyond the surface of bed and side joints. The requirements regarding bushing shall be the same as for random rubble masonry.

1405.4.2 Hearting stones : The hearting or interior filling of the wall face shall consist of flat bedded stone carefully laid, on prepared beds in mortar. The use of chips shall be restricted to the filling of interstices between the adjacent stones in hearting and these shall not exceed 10 percent of the quantity of masonry. While using chips it shall be ensured that no hollow spaces are left anywhere in the masonry.

1405.4.3 Bond stones : The requirements regarding through or bond stone shall be the same as for random rubble masonry, but these, shall be provided at 1.5 metre to 1.8 metre apart clear in every course.

1405.4.4 Quoin stone : The quoins shall be of the same height of the course in which these occur and shall be formed of header stones not less than 450 mm in length. They shall be laid lengthwise alternately along each face, square in their beds which shall be fairly dressed to a depth of a least 100 mm

1405.4.5 Face stone : Face stones shall tail into the work for not less than their heights and at least one-third of the stones shall tail into the work for a length not less than twice their height. These shall be laid as headers and stretchers alternately.

1405.4.6 Laying : The stones shall be laid on horizontal courses and all vertical joints should be truly vertical. The quoin stones should be laid header and stretcher alternately and shall be laid square on their beds, which shall be rough chisel dressed to a depth of at least 100 mm.

1405.4.7 Joints : The face joints shall not be more than 10 mm thick, but shall be sufficiently thick to prevent stone-to-stone contact and shall be completely filled with mortar.

1405.5 Ashlar Masonry (Plain Ashlar)

1405.5.1 Dressing : Every stone shall be cut to the required size and shape, chisel dressed on all beds and joints so as to be free from all bushing. Dressed surface shall not show a depth of gap of more than 3 mm from straight edge placed on it. The exposed faces and joints, 6 mm from the face shall be fine tooled so that a straight edge can be laid along the face of the stone in contact with every point. All visible angles and edges shall be true and square and free from chippings. The corner stones (quoins) shall be dressed square and corner shall be straight and vertical.

1405.5.2 Bond Stones : Through bond stones shall be provided in masonry upto 600 mm thickness and in case of masonry above 600 mm thickness, a set of two or more bond stones overlapping each other at least by 150 mm shall be provided in a line from face to back. In case of highly absorbent types of stones (porous limestone and sandstones, etc.,) the bond stone shall extend only about two-thirds into the wall, as through stones in such cases may give rise to penetration of dampness and, therefore, for all thickness of such masonry a set of two or more bond stones overlapping each other by at

least 150 mm shall be provided. One bond stone or a set of bond stones shall be 1.5 metres to 1.8 metres apart clear in every course.

1405.5.3 Laying : The face stone shall be laid header and stretcher alternately, the header being arranged to come as nearly as possible in the middle of stretchers above and below. Stones shall be laid in regular courses not less than 300 mm in height and all courses of the same height unless otherwise specified. No stone shall be less in width than its height or less in length than twice its height, unless otherwise specified.

1405.5.4 Joints : All joints shall be full of mortar. These shall not be less than 3 mm thick. Face joints shall be uniform throughout, and a uniform recess of 20 mm depth from face shall be left with the help of a stone plate during the progress of work.

1405.6 Pointing

Pointing shall be carried out using mortar not leaner than 1:3 by volume of cement and sand or as shown on the drawing. The mortar shall be filled and pressed into the raked out joints before giving the required finish. The pointing shall conform to Clause 1312.3 of these Specification. The work shall conform to IS:2212. The thickness of joints shall not be less than 3 mm for Ashlar masonry. However, the maximum thickness of joints in different works shall be as follows:

Random Rubble	:	20 mm
Coursed Rubble	:	15 mm
Ashlar Mansory	:	5 mm

1405.7 Curing

Curing shall conform to Clauses 1309 and 1312.5

1405.8 Scaffolding

For scaffolding, Clause 1310 shall apply.

1405.9 Weep Holes

Weep holes shall conform to Clauses 2706.

1405.10 Jointing with Existing Structures

For jointing with existing structures, the Specifications given under Clause 1308 shall apply.

1406 ARCHITECTURAL COPING FOR WING/RETURN/PARAPET WALLS

Architectural coping for wing/return/parapet walls shall conform to Clause 1313.

1407 TESTS AND STANDARDS OF ACCEPTANCE

All work shall be done to the lines and levels as indicated on the drawing or as directed by the Engineer subject to tolerances as specified in these Specifications.

Mortar cubes shall be taken in accordance with IS:2250 for compressive strength, consistency of mortar and its water retentivity. The frequency of testing shall be one sample for every two cubic metres of mortar subject to a minimum of 3 samples for a day's work.

1408 MEASUREMENTS FOR PAYMENT

1408.1 Stone masonry shall be measured in cubic metres.

1408.2 In arches, the length of arch shall be measured as the mean length between the extrados and intrados.

1408.3 The work of pointing shall be measured in square metres.

1408.4 Architectural coping shall be measured in linear metres.

1409 RATE

1409.1 The contract unit rate for stone masonry shall include the cost of all labour, materials, tools and plant, scaffolding, sampling and testing, supervision and other expenses incidental to the satisfactory completion of the work as described in these Specifications.

1409.2 The contract unit rate for pointing shall include erecting and removal of scaffolding, all labour, materials and equipment incidental to complete pointing, raking out joints, cleaning, wetting, filling with mortar, trowelling, pointing and watering, sampling and testing and supervision as described in these Specifications.

1409.3 The contract rate for architectural coping shall include the cost of all labour, materials, tools and plant, sampling and testing and supervision as described in these specifications.

1500

Formwork

1501 DESCRIPTION

Formwork shall include all temporary or permanent forms required for forming the concrete of the shape, dimensions and surface finish as shown on the drawing or as directed by the Engineer, together with all props, staging, centering, scaffolding and temporary construction required for their support. The design, erection and removal of formwork shall conform to IRC:87 "Guidelines for Design and Erection of Falsework for Road Bridges" and these Specifications.

1502 MATERIALS

All materials shall comply with the requirements of IRC:87. Materials and components used for formwork shall be examined for damage or excessive deterioration before use/ re-use and shall be used only if found suitable after necessary repairs. In case of timber formwork, the inspection shall not only cover physical damages but also signs of attacks by decay, rot or insect attack or the development of splits.

Forms shall be constructed with metal or timber. The metal used for forms shall be of such thickness that the forms remain true to shape. All bolts should be countersunk. The use of approved internal steel ties or steel or plastic spacers shall be permitted. Structural steel tubes used as support for forms shall have a minimum wall thickness of 4 mm. Other materials conforming to the requirements of IRC:87 may also be used if approved by the Engineer.

1503 DESIGN OF FORMWORK

1503.1 The Contractor shall furnish the design and drawing of complete formwork (i.e. the forms as well as their supports) for approval of the Engineer before any erection is taken up. If proprietary system of formwork is used, the Contractor shall furnish detailed information as per *Appendix 1500/I* to the Engineer for approval.

Notwithstanding any approval or review of drawing and design by the Engineer, the Contractor shall be entirely responsible for the adequacy and safety for formwork.

1503.2 The design of the formwork shall conform to provisions of IRC:87. It shall ensure that the forms can be conveniently removed without disturbing the concrete. The design shall facilitate proper and safe access to all parts of formwork for inspection.

1503.3 In the case of prestressed concrete superstructure, careful consideration shall be given to redistribution of loads on props due to prestressing.

1504 WORKMANSHIP

1504.1 The formwork shall be robust and strong and the joints shall be leak-proof.

Balli shall not be used as staging. Staging must have cross bracings and diagonal bracings in both directions. Staging shall be provided with an appropriately designed base plate resting on firm strata.

1504.2 The number of joints in the formwork shall be kept to a minimum by using large size panels. The design shall provide for proper “soldiers” to facilitate alignment. All joints shall be leak proof and must be properly sealed. Use of PVC JOINT sealing tapes, form rubber or PVC T-section is essential to prevent leakage of grout.

1504.3 As far as practicable, clamps shall be used to hold the forms together. Where use of nails is unavoidable, minimum number of nails shall be used and these shall be left projecting so that they can be withdrawn easily. Use of double headed nails shall be preferred.

1504.4 Use of ties shall be restricted, as far as practicable. Wherever ties are used they shall be used with HDPE sheathing so that the ties can easily be removed. No parts prone to corrosion shall be left projecting or near the surface. The sheathing shall be grouted with cement mortar of the same strength as that of the structure.

1504.5 Unless otherwise specified, or directed, chamfers or fillets of size 25 mm x 25 mm shall be provided at all angles of the formwork to avoid sharp corners. The chamfers, beveled edges and mouldings shall be made in the formwork itself. Opening for fixtures and other fittings shall be provided in the shuttering as directed by the Engineer.

1504.6 Shuttering for walls, sloping members and thin sections of considerable height shall be provided with temporary openings to permit inspection and cleaning out before placing of concrete.

1504.7 The formwork shall be constructed with pre-camber to the soffit to allow for deflection of the formwork. Pre-camber to allow for deflection of formwork shall be in addition to that indicated for the permanent structure in the drawings.

1504.8 Where centering trusses or launching trusses are adopted for casting of superstructure, the joints of the centering trusses, whether welded, riveted or bolted should be thoroughly checked periodically. Also, various members of the centering trusses should be periodically examined for proper alignment and unintended deformation before proceeding with the concreting. They shall also be periodically checked for any deterioration in quality due to steel corrosion.

1504.9 The formwork shall be so made as to produce a finished concrete true to shape, line and levels and dimensions as shown on the drawings, subject to the tolerances specified in respective sections of these Specifications, or as directed by the Engineer.

1504.10 Where metal forms are used, all bolts and rivets shall be countersunk and well ground to provide a smooth, plane surface. Where timber is used it shall be well seasoned, free from loose knots, projecting nails, splits or other defects that may mar the surface of concrete.

1504.11 Forms shall be made sufficiently rigid by the use of ties and bracings to prevent any displacement or sagging between supports. They shall be strong enough to withstand all pressure, ramming and vibration during and after placing the concrete. Screw jacks or hard wood wedges where required shall be provided to make up any settlement in the formwork either before or during the placing of concrete.

1504.12 The formwork shall take due account of the calculated amount of positive or negative camber so as to ensure the correct final shape of the structures, having regard to the deformation of falsework, scaffolding or propping and the instantaneous or deferred deformation due to various causes affecting prestressed structures.

1504.13 Suitable camber shall be provided to horizontal members of structure, specially in long spans to counteract the effects of deflection. The formwork shall be so fixed as to provide for such camber.

1504.14 The formwork shall be coated with an approved release agent that will effectively prevent sticking and will not stain the concrete surface. Lubricating (machine oils) shall be prohibited for use as coating.

1505 FORMED SURFACE AND FINISH

The formwork shall be lined with material approved by the Engineer so as to provide a smooth finish of uniform texture and appearance. This material shall leave no stain on the concrete and so fixed to its backing as not to impart any blemishes. It shall be of the same type and obtained from only one source throughout for the construction of any one structure. The Contractor shall make good any imperfections in the resulting finish as required by the Engineer. Internal ties and embedded metal parts shall be carefully detailed and their use shall be subject to the approval of the Engineer.

1506 PRECAUTIONS

i) Special measures in the design of formwork shall be taken to ensure that it does not hinder the shrinkage of concrete. The soffit of the formwork shall be so designed as to ensure that the formwork does

not restrain the shortening and/or hogging of beams during prestressing. The forms may be removed at the earliest opportunity subject to the minimum time for removal of forms with props retained in position.

ii) Where necessary, formwork shall be so arranged that the soffit form, properly supported on props only can be retained in position for such period as may be required by maturing conditions.

iii) Any cut-outs or openings provided in any structural member to facilitate erection of formwork shall be closed with the same grade of concrete as the adjoining structure immediately after removal of formwork ensuring watertight joints.

iv) Provision shall be made for safe access on, to and about the formwork at the levels as required.

v) Close watch shall be maintained to check for settlement of formwork during concreting. Any settlement of formwork during concreting shall be promptly rectified.

vi) Water used for curing should not be allowed to stagnate near the base plates supporting the staging and should be properly drained.

1507 PREPARATION OF FORMWORK BEFORE CONCRETING

The inside surfaces of forms shall, except in the case of permanent formwork or where otherwise agreed to by the Engineer be coated with a release agent supplied by approved manufacturer or of an approved material to prevent adhesion of concrete to the formwork. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not be allowed to come into contact with any reinforcement or prestressing tendons and anchorages. Different release agents shall not be used in formwork for exposed concrete.

Before re-use of forms, the following actions shall be taken :

i) The contact surfaces of the forms shall be cleaned carefully and dried before applying a release agent.

ii) It should be ensured that the release agent is appropriate to the surface to be coated. The same type and make of release agent shall be used throughout on similar formwork materials and different types should not be mixed.

iii) The form surfaces shall be evenly and thinly coated with release agent. The vertical surface shall be treated before horizontal surface and any excess wiped out.

iv) The release agent shall not come in contact with reinforcement or the hardened concrete.

All forms shall be thoroughly cleaned immediately before concreting.

The Contractor shall give the Engineer due notice before placing any concrete in the forms to permit him to inspect and approve the formwork. However, such inspection shall not relieve the Contractor of his responsibility for safety of formwork, men, machinery, materials and finish or tolerances of concrete.

1508 REMOVAL OF FORMWORK

The scheme for removal of formwork (i.e. de-shuttering and de-centering) shall be planned in advance and furnished to the Engineer for scrutiny and approval. No formwork or any part thereof shall be removed without prior approval of the Engineer.

The formwork shall be so removed as not to cause any damage to concrete. Centering shall be gradually and uniformly lowered in such a manner as to permit the concrete to take stresses due to its own weight uniformly and gradually to avoid any shock or vibration.

Where not specifically approved, the time of removal of formwork (when ordinary Portland Cement is used without any admixtures at an ambient temperatures exceeding 10°C) shall be as under :

a)	Walls, piers, abutments, columns and vertical faces of structural members	:	12 to 48 hours as may be decided by the Engineer
b)	Soffits of Slabs (with props left under)	:	3 days
c)	Props (left under slabs)	:	14 days
d)	Soffits of Girders (with props left under)	:	7 days
e)	Props (left under girders)	:	21 days

Where there are re-entrant angles in the concrete sections, the formwork should be removed at these sections as soon as possible after the concrete has set, in order to avoid cracking due to shrinkage of concrete.

1509 RE-USE OF FORMWORK

When the formwork is dismantled, its individual components shall be examined for damage and damaged pieces shall be removed for rectification. Such examination shall always be carried out before their use again. Before re-use all components shall be cleaned of deposits of soil, concrete or other unwanted materials. Threaded parts shall be oiled after cleaning.

All bent steel props shall be straightened before re-use. The maximum deviation from straightness is 1/600 of the length. The maximum permissible axial loads in used props shall be suitably reduced depending upon their condition. The condition of the timber components, plywood and steel shuttering plates shall be examined closely for distortion and defects before re-use.

1510 SPECIALISED FORMWORK

Specialised formwork may be required in the case of slipform work, underwater concreting, segmental construction etc. Such specialised formwork shall be designed and detailed by competent agencies and a set of complete working drawings and installation instructions shall be supplied to the Engineer. The site personnel shall be trained in the erection and dismantling as well as operation of such specialised formwork. In case proprietary equipment is used, the supplier shall supply drawings, details, installation instructions, etc. in the form of manuals along with the formwork. Where specialised formwork is used, close co-ordination with the design of permanent structure is necessary.

For slipform the rate of slipping the formwork shall be designed for each individual case taking into account various parameters including the grade of concrete, concrete strength, concrete temperature, ambient temperature, concrete admixtures, etc. In the case of segmental construction, the concrete mix shall be normally designed for developing high early strength so that the formwork is released as early as possible.

In order to verify the time and sequence of striking/removal of specialised formwork, routine field tests for the consistency of concrete and strength development are mandatory and shall be carried out before adoption.

For specialised formwork, the form lining material may be either plywood or steel sheet of appropriate thickness. Plywood is preferred where superior quality of surface is desired, whereas steel sheeting is normally used where large number of repetitions are involved.

1511 TESTS AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

1512 MEASUREMENTS FOR PAYMENT

Unless stated otherwise, the rate for concrete in Plain Concrete or Reinforced Concrete or Prestressed Concrete shall be deemed to include all formwork required in accordance with this section and shall not be measured separately.

Where it is specifically stipulated in the Contract that the formwork shall be paid for separately, measurement of formwork shall be taken in square metres of the surface area of concrete which is in contact with formwork.

1513 RATE

The unit rate of the Plain Concrete or Reinforced Concrete or Prestressed Concrete as defined in respective sections shall be deemed to cover the costs of all formwork, including cost of all materials, labour, tools and plant required for design, construction and removal of formwork and supervision as described in this section including properly supporting the members until the concrete is cured, set and hardened as required.

Where the contract unit rate for formwork is specially provided as a separate item in the contract, it shall include the cost of all materials, labour, tools and plant required for design, construction and removal of formwork and supervision as described in this Section including properly supporting the members until the concrete is cured, set and hardened as required.

1600

Steel Reinforecement (Untensioned)

1601. DESCRIPTION

This work shall consist of furnishing and placing coated or uncoated mild steel or high strength deformed reinforcement bars (untensioned) of the shape and dimensions shown on the drawings and conforming to these Specifications or as approved by the Engineer.

1602. GENERAL

Steel for reinforcement shall meet with the requirements of Section 1000.

Reinforcements may be either mild steel/medium tensile steel or high strength deformed bars. They may be uncoated or coated with epoxy or with approved protective coatings.

1603. PROTECTION OF REINFORCEMENT

Uncoated reinforcing steel shall be protected from rusting or chloride contamination. Reinforcements shall be free from rust, mortar, loose mill scale, grease, oil or paints. This may be ensured either by using reinforcement fresh from the factory or thoroughly cleaning all reinforcement to remove rust using any suitable method such as sand blasting, mechanical wire brushing, etc., as directed by the Engineer. Reinforcements shall be stored on blocks, racks or platforms and above the ground in a clean and dry condition and shall be suitably marked to facilitate inspection and identification.

Portions of uncoated reinforcing steel and dowels projecting from concrete, shall be protected within one week after initial placing of concrete with a brush coat of neat cement mixed with water to a consistency of thick paint. This coating shall be removed by lightly tapping with a hammer or other tool not more than one week before placing of the adjacent pour of concrete. Coated reinforcing steel shall e protected against damage to the coating. If the coating on the bars is damaged during transportation or handling and cannot be repaired, the same shall be rejected.

1604. BENDING OF REINFORCEMENT

Bar bending schedule shall be furnished by the Contractor and got approved by the Engineer before start of work.

Reinforcing steel shall conform to the dimensions and shapes given in the approved Bar Bending Schedules.

Bars shall be bent cold to the specified shape and dimensions or as directed by the Engineer using a proper bar bender, operated by hand or power to obtain the correct radii of bends and shape.

Bars shall not be bent or straightened in a manner that will damage the parent material or the coating.

Bars bent during transport or handling shall be straightened before being used on work and shall not be heated to facilitate straightening.

1605. PLACING OF REINFORCEMENT

a) The reinforcement cage should generally be fabricated in the yard at ground level and then shifted and placed in position. The reinforcement shall be placed strictly in accordance with the drawings and shall be assembled in position only when the structure is otherwise ready for placing of concrete. Prolonged time gap between assembling of reinforcement and casting of concrete, which may result in rust formation on the surface, shall not be permitted.

b) Reinforcement bars shall be placed accurately in position as shown on the drawings. The bars, crossing one another shall be tied together at every intersection with binding wire (annealed), conforming to IS:280 to make the skeleton of the reinforcement rigid such that the reinforcement does not get displaced during placing of concrete, or any other operation. The diameter of binding wire shall not be less than 1 mm.

c) Bars shall be kept in position usually by the following methods:

(i) In case of beam and slab construction, industrially produced polymer cover blocks of thickness equal to the specified cover shall be placed between the bars and formwork subject to satisfactory evidence that the polymer composition is not harmful to concrete and reinforcement. Cover blocks made to concrete may be permitted by the Engineer, provided they have the same strength and specification as those of the member.

(ii) In case of dowels for columns and walls, the vertical reinforcement shall be kept in position by means of timber templates with slots cut in them accurately, or with cover blocks tied to the reinforcement. Timber templates shall be removed after the concreting has progressed upto a level just below their location.

(iii) Layers of reinforcements shall be separated by spacer bars at approximately one metre intervals. The minimum diameter of spacer bars shall be 12 mm or equal to maximum size of main reinforcement or maximum size of coarse aggregate, whichever is greater.

Horizontal reinforcement shall not be allowed to sag between supports.

(iv) Necessary stays, blocks, metal chairs, spacers, metal hangers, supporting wires etc. or other subsidiary reinforcement shall be provided to fix the reinforcements firmly in its correct position.

(v) Use of pebbles, broken stone, metal pipe, brick, mortar or wooden blocks etc., as devices for positioning reinforcement shall not be permitted.

d) Bars coated with epoxy or any other approved protective coating shall be placed on supports that do not damage the coating. Supports shall be installed in a manner such that planes of weakness are not created in hardened concrete. The coated reinforcing steel shall be held in place by use of plastic or plastic coated binding wires especially manufactured for the purpose. Reference shall be made to Section 1000 for other requirements.

e) Placing ad fixing of reinforcement shall be inspected and approved by the Engineer before concrete is deposited.

1606. BAR SPLICES

1606.1. Lapping

All reinforcement shall be furnished in full lengths as indicated on the drawing. No splicing of bars, except where shown on the drawing, will be permitted without approval of the Engineer. The lengths of the splice shall be as indicated on drawing or as approved by the Engineer. Where practicable, overlapping bars shall not touch each other, and shall be kept apart by 25 mm or 1 $^{1/4}$ times the maximum size of coarse aggregate, whichever is greater. If this is not feasible, overlapping bars shall be bound with annealed steel binding wire not less than 1 mm diameter and twisted tight in such a manner as to maintain minimum clear cover to the reinforcement from the concrete surface. Lapped splices shall be staggered or located at points, along the span where stresses are low.

1606.2. Welding

1606.2.1. Splicing by welding of reinforcement will be permitted only if detailed on the drawing or approved by the Engineer. Weld shall develop an ultimate strength equal to or greater than that of the bars connected.

1606.2.2. While welding may be permitted for mild steel reinforcing bars conforming to IS:432, welding of deformed bars conforming to IS:1786 shall in general be prohibited.

Welding may be permitted in case of bars of other than S 240 grade including special welding grade of S 415 grade bars conforming to IS:1786, for which necessary chemical analysis has been secured and the carbon equivalent (CE) calculated from the chemical composition using the formula :

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mg+V}{5} + \frac{Ni+Cu}{15}$$

is 0.4 or less.

1606.2.3. The method of welding shall conform to IS:2751 and IS:9417 and to any supplemental specifications to the satisfaction of the Engineer.

Welding may be carried out by metal are welding process. Oxy-acetelene welding shall not be permissible. Any other process may be used subject to the approval of the Engineer and necessary additional requirements to ensure satisfactory joint performance. Precautions on over heating, choice of electrode, selection of correct current in are welding etc., should be strictly observed.

All bars shall be butt welded except for smaller diameter bars (diameter of less than 20 mm) which may be lap welded. Single-V or Double-V butt joints may generally be used. For vertical bars single bevel or double bevel joints may be used.

Welded joints shall be located well away from bends and not less than twice the bar diameter away from a bend.

Generally, shop welding in controlled conditions is to be preferred, where feasible. Site welding where necessary shall, however, be permitted when the facilities, equipment, process, consumables, operators, welding procedure are adequate to produce and maintain uniform quality at par with that attainable in shop welding to the satisfaction of the Engineer.

Joint welding procedures which are to be employed shall invariably be established by a procedure specification. All welders and welding operators to be employed shall have to be qualified by tests prescribed in IS:2751. Inspection of welds shall conform to IS:822 and destructive or non-destructive testing may be undertaken when deemed necessary. Joints with weld defects detected by visual inspection or dimensional check inspection shall not be accepted.

Suitable means shall be provided for holding the bars securely in position during welding. It must be ensured that no voids are left in welding. When welding is done in 2 or 3 stages, previous surface shall be cleaned properly. Bars shall be cleaned of all loose scale, rust, grease, paint and other foreign matter before carrying out welding . Only competent and experienced welders shall be employed on the work with the approval of the Engineer. No welding shall be done on coated bars.

M.S. electrodes used for welding shall conform to IS:814.

1606.2.4. Welded joints shall preferably be located at points where steel will not be subject to more than 75 per cent of the maximum permissible stresses and welds so staggered that at any one section, not more than 20 per cent of the bars are welded.

1606.2.5. Welded pieces of reinforcement shall be tested. Specimens shall be taken from the site and the number and frequency of tests shall be as directed by the Engineer.

1606.3. Mechanical Coupling of Bars

Bars may be joined with approved patented mechanical devices as indicated on the drawing or as approved by the Engineer e.g. by special grade steel sleeves swagged on to bars in end to end contact or by screwed couplers. In case such devices are permitted by the Engineer, they shall develop at least 125 per cent of the characteristic strength of the reinforcement bar.

1607. TESTING AND ACCEPTANCE

The material shall be tested in accordance with relevant IS specifications and necessary test certificates shall be furnished. Additional tests, if required, will be got carried out by the Contractor at his own cost.

The fabrication, furnishing and placing of reinforcement shall be in accordance with these specifications and shall be checked and accepted by the Engineer.

Manufacturer's test certificate regarding compliance with the Indian Standards for each lot of steel shall be obtained and submitted to the Engineer. If required by the Engineer, the Contractor shall carry out confirmatory tests in the presence a person authorized by the Engineer. Cost of these tests shall be borne by the Contractor. The sampling and testing procedure shall be as laid down in IS 1786. If any test piece selected from a lot fails, no retesting shall be done and lot shall be rejected.

1608. MEASUREMENT FOR PAYMENT

Reinforcement shall be measured in length including hooks, if any, separately for different diameters as actually used in work, excluding overlaps. From the length so measured, the weight of reinforcement shall be calculated in tones on the basis of IS:1732. Wastage, overlaps, couplings, welded joints, spacer bars, chairs, stays, hangers and annealed steel wire or other methods for binding and placing shall not be measured and cost of these items shall be deemed to be included in the rates for reinforcement.

1609. RATE

The contract unit rate for coated/uncoated reinforcement shall cover the cost of material, fabricating, transporting, storing, bending, placing, binding and fixing in position as shown on the drawings as per these specifications and as directed by the Engineer, including all labour, equipment, supplies, incidentals, sampling, testing and supervision.

The unit rate for coated reinforcement shall be deemed to also include cost of all material, labour, tools and plant, royalty, transportation and expertise required to carry out the work. The rate shall also cover sampling, testing and supervision required for the work.

1700

Structural Concrete

1701 DESCRIPTION

The work shall consist of furnishing concrete mixes, transporting and placing structural concrete including fixing formwork and temporary works etc. and incidental construction in accordance with these Specifications and in conformity with the lines, grades and dimensions, as shown on the drawings or as directed by the Engineer.

1702 MATERIALS

All materials shall conform to Section 1000 of these Specifications.

1703 GRADES OF CONCRETE

1703.1 The grades of concrete shall be designated by the characteristic strength as given in Table 1700-1, where the characteristic strength is defined as the strength of concrete below which not more than 5 percent of the test results are expected to fall.

Table 1700-1

Group	Grade Designation	Specified characteristic compressive strength of 150 mm cubes at 28 days, in MPa
Ordinary Concrete	M 15	15
	M 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High strength Concrete*	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

* For high strength concrete, design parameters may be obtained from the specialized literature and experimental results.

1703.2 The lowest grades of concrete in bridges and corresponding minimum cement contents and water-cement ratios shall be maintained as indicated in Tables 1700-2 and 1700-3

Table 1700-2 For Bridges With Prestressed Concrete or those with Individual Span Lengths More than 60 M or those that are Built with Innovative Design/Construction.

(A) Minimum Cement Content and Maximum Water Cement Ratio

Structural Member	Min. cement content for all exposure conditions (kg/cu.m)	Max. water cement ratio for all exposure conditions
a) PCC members	360	0.45
b) RCC members	380	0.45
c) PSC members	400	0.40

(B) Minimum Strength of Concrete

Member	Conditions of Exposure	
	Moderate	Severe
a) PCC members	M 25	M 30
b) RCC members	M 35	M 35
c) PSC members	M 35	M 40

Table 1700-3 For Bridges other than those Mentioned in Table 1700-2 and for Culverts and other Incidental Construction

(A) Minimum Cement Content and Maximum Water Cement Ratio

Structural Member	Min. cement content (kg/cu.m)		Max. water cement ratio	
	Exposure conditions		Exposure conditions	
	Moderate	Severe	Moderate	Severe
a) PCC members	250	310	0.50	0.45
b) RCC members	310	360	0.45	0.40

(B) Minimum Strength of Concrete

Member	Conditions of Exposure	
	Moderate	Severe
a) PCC members	M 15	M 20
b) RCC members	M 20	M 25

Notes Applicable to Tables 1700-2 and 1700-3

i) The minimum cement content is based on 20 mm aggregates (nominal max. size). For 40 mm and larger size aggregates, it may be reduced suitably but the reduction shall not be more than 10 percent.

ii) For underwater concreting, the cement content shall be increased by 10 percent.

iii) Severe conditions of exposure shall mean alternate wetting and drying due to sea spray, alternate wetting and drying combined with freezing and buried in soil having corrosive effect, members in contact with water where the velocity of flow and the bed material are likely to cause erosion of concrete.

(iv) Moderate conditions of exposure shall mean other that those mentioned in (iii) above.

The cement content shall be as low as possible but not less than the quantities specified above. In no case shall it exceed 450 kg/cu.m of concrete.

1703.3 Concrete used in any component or structure shall be specified by designation along with prescribed method of design of mix i.e. “Design Mix” or “Nominal Mix”. For all items of concrete, only “Design Mix” shall be used, except where “Nominal Mix” concrete is permitted as per drawing or by the Engineer. “Nominal Mix” may be permitted only for minor bridges and culverts or other incidental construction where strength requirements are upto M 20 only. “Nominal Mix” may also be permitted for non-structural concrete or for screed below open foundations.

1703.4 If the Contractor so elects, the Engineer may permit the use of higher grade concrete than that specified on the drawing, in which event the higher grade concrete shall meet the specifications applicable thereto without additional compensation.

1704 PROPORTIONING OF CONCRETE

Prior to the start of construction, the Contractor shall design the mix in case of “Design Mix Concrete” or propose nominal mix in case of “Nominal Mix Concrete”, and submit to the Engineer for approval, the proportions of materials, including admixtures to be used. Water-reducing admixtures (including plasticisers or super-plasticisers) may be used at the Contractor’s option, subject to the approval of the Engineer. Other types of admixtures shall be prohibited, unless specifically permitted by the Engineer.

1704.1 Requirements of Consistency

The mix shall have the consistency which will allow proper placement and consolidation in the required position. Every attempt shall be made to obtain uniform consistency. Slump test shall be used to measure consistency of the concrete.

The optimum consistency for various types of structures shall be as indicated in Table 1700-4, or as directed by the Engineer. The slump of concrete shall be checked as per IS:516.

Table 1700-4

	Type		SLUMP (mm) (at the time of placing of concrete)
1	a)	Structure with exposed inclined surface requiring low slump concrete to allow proper compaction	25
	b)	plain cement concrete	25
2.	RCC structure with widely spaced reinforcements; e.g. solid columns, piers, abutments, footings, well steining		40 - 50
3.	RCC structure with fair degree of congestion of reinforcement; e.g. pier and abutment caps, box culverts, well curb, well cap, walls with thickness greater than 300 mm		50 - 75
4.	RCC and PSC structure with highly congested reinforcements e.g. deck slab girders, box girders, walls with thickness less than 300 mm		75 - 125
5.	Underwater concreting through tremie e.g. bottom plug, cast-in-situ piling		100 - 150

However, notwithstanding the optimum consistency indicated under Sl. No. 1 to 3, the situation at hand should be property assessed to arrive at desired workability with the adjustment in admixture in each case where the concrete is to be transported through transit mixer and placed using concrete pump. Under these circumstances, the optimum consistency during placement for the item of mark from Sl. No. 1 to 3 can be considered ranging from 50-100 mm this is, however, subject to satisfying the other essential criteria of strength, durability, finishing in trial mix design stage and approval of the Engineer.

1704.2 Requirements for Design Mixes

1704.2.1 Target mean strength

The target mean strength of specimen shall exceed the specified characteristic compressive strength by at least the “current margin”.

i) The current margin for a concrete mix shall be determined by the Contractor and shall be taken as 1.64 times the standard deviation of sample test results taken from at least 40 separate batches of concrete of nominally similar proportions produced at site by the same plant under similar supervision, over a period exceeding 5 days, but not exceeding 6 months.

ii) Where there is insufficient data to satisfy the above, the current margin for the initial design mix shall be taken as given in Table 1700-5 :

Table 1700-5

Concrete Grade	Current Margin (MPa)	Target Mean Strength (MPa)
M 15	10	25
M 20	10	30
M 25	11	36
M 30	12	42
M 35	12	47
M 40	12	52
M 45	13	58
M 50	13	63
M 55	14	69
M60	14	74

The initial current margin given in Table 1700-5 shall be used till sufficient data is available to determine the current margin as per sub-clause (i) above.

1704.2.2 Trial mixes

The Contractor shall give notice to the Engineer to enable him to be present at the making of trial mixes and preliminary testing of the cubes. Prior to commencement of trial mix design, all materials forming constituents of proposed design mix should have been tested and approval obtained in writing from the Engineer. Based on test results of material, draft mix design calculation for all grades shall be prepared taking into account the provisions in the Contract Technical Specifications, guidelines of IS:10262 IRC:SP:23, IRC:21 and submitted to the Engineer for approval. Prior to commencement of concreting,

trial mix design shall be performed for all grades of concrete, and trial mix which has been found successful should be submitted by the Contractor and approval obtained. During concreting with the approved Trial Mix Design, if source of any constituents is changed, the mix design shall be revised and tested for satisfying the strength requirements.

The initial trial mixes shall generally be carried out in an established laboratory approved by the Engineer. In exceptional cases, the Engineer may permit the initial trial mixes to be prepared at the site laboratory of the Contractor, if a full fledged concrete laboratory has been established well before the start of construction, to his entire satisfaction. In all cases complete testing of materials forming the constituents of proposed Design Mix shall be carried out prior to making trial mixes.

Sampling and testing procedures shall be in accordance with these Specifications.

When the site laboratory is utilized for preparing initial mix design, the concreting plant and means of transport employed to make the trial mixes shall be similar to that proposed to be used in the works.

Test cubes shall be taken from trial mixes as follows. For each mix, set of six cubes shall be made from each of three consecutive batches. Three cubes from each set of six shall be tested at an age of 28 days and three at an earlier age approved by the Engineer. The cubes shall be made, cured, stored, transported and tested in accordance with these Specifications. The average strength of the nine cubes at 28 days shall exceed the specified characteristic strength by the current margin minus 3.5 MPa

1704.2.3 Control of strength of design mixes

a) Adjustment to Mix Proportion

Adjustment to mix proportions arrived at in the trial mixes shall be made subject to the Engineer's approval, in order to minimize the variability of strength and to maintain the target mean strength. Such adjustments shall not be taken to imply any change in the current margin.

b) Change of Current Margin

When required by the Engineer, the Contractor shall recalculate the current margin in accordance with Clause 1704.2.1. The recalculated value shall be adopted as directed by the Engineer, and it shall become the current margin for concrete produced subsequently.

c) Additional Trial Mixes

During production, the Contractor shall carry out trial mixes and tests, if required by the Engineer, before substantial changes are made in

the material or in the proportions of the materials to be used, except when adjustments to the mix proportions are carried out in accordance with sub-clause (a) above

1704.3 Requirements of Nominal Mix Concrete

Requirements for nominal mix concrete unless otherwise specified, shall be as given in Table 1700-6.

Table 1700-6 Proportions for Nominal Mix Concrete

Concrete Grade	Total Quantity of dry aggregate by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse aggregates (kg)	Proportion of fine to coarse aggregate (by mass)	Maximum quantity of water for 50 kg of cement (litres)	
			PCC	RCC
M 15	350	Generally 1:2, subject to upper limit 1:1.5 and lower limit of 1:2.5	25	
M 20	250		25	22

1704.4 Additional Requirements

Concrete shall meet any other requirements as specified on the drawing or as directed by the Engineer. Additional requirements shall also consist of the following overall limits of deleterious substances in concrete :

a) The total chloride content of all constituents of concrete as a percentage of mass of cement in mix shall be limited to values given below:

- Prestressed Concrete : 0.1 percent
- Reinforced concrete exposed to chlorides in service (e.g.structures located near sea coast) : 0.2 percent
- Other reinforced concrete construction : 0.3 percent

b) The total sulphuric anhydride (SO) content of all the constituents of concrete as a percentage of mass of cement in the mix shall be limited to 4 percent.

1704.5 Suitability of Proposed Mix Proportions

The Contractor shall submit the following information for the Engineer's approval :

a) Nature and source of each material

b) Quantities of each material per cubic metre of fully compacted concrete

c) Either of the following :

   i) appropriate existing data as evidence of satisfactory previous performance for the target mean strength, current margin, consistency and water/cement ratio and any other additional requirement (s) as specified.

   ii) full details of tests on trial mixes.

d) Statement giving the proposed mix proportions for nominal mix concrete

Any change in the source of material or in the mix proportions shall be subject to the Engineer's prior approval.

1704.6 Checking of mix proportions and water cement ratio

In proportioning concrete, the quantity of both cement and aggregate shall be determined by weight. Where the weight of cement is determined by accepting the manufacturer's weight per bag, a reasonable number of bags shall be weighed separately to check the net weight. Where cement is weiged from bulk stock at site and not by bag, it shall be weighed separately from the aggregates. Water shall either be measured by volume in calibrated tanks or weighed. All measuring equipment shall be maintained in a clean and serviceable condition. Their accuracy shall be periodically checked.

It is most important to keep the specified water cement ratio constant and at its correct value. To this end, moisture content in both fine and coarse aggregates shall be determined as frequently as possible, frequency for a given job being determined by the Engineer according to the weather conditions. The amount of mixing water shall then be adjusted to compensate for variations in the moisture content. For the determination of moisture content in the aggregates IS:2386 (part III) shall be referred to. Suitable adjustments shall also be made in the weight of aggregates to allow for the variation in weight of aggregates due to variation in their moisture content.

1704.7 Grading of aggregates for concrete

Materials for pumped concrete shall be batched consistently and uniformly. Maximum size of aggregate shall not exceed one-third of the internal diameter of the pipe.

The grading of aggregates shall be continuous and shall have sufficient ultra fine materials (material finer than 0.25 mm). Proportion of fine aggregates passing through 0.25 mm shall be between 15 and 30 percent and that passing through 0.125 mm sieve shall not be less than 5 percent of the total volume of aggregate. Admixtures to increase workability can be added. When pumping long distances and in hot weather, set-retarding admixtures can be used. Fluid mixes can be pumped satisfactorily after adding plasticisers and super plaslicisers. Suitability of concrete shall be verified by trial mixes and by performing pumping test.

1705 ADMIXTURES

Use of admixtures such as superplasticisers, air extraining, water reducing, accelerating retardation etc for concrete may be made with the approval of the Engineer.

As the selection of an appropriate concrete admixture is an integral part of the mix design, the manufacturers shall recommend the use of any one of their products only after obtaining complete knowledge of all the actual constituents of concrete as well as methodologies of manufacture, transportation and compaction of concrete proposed to be used in the work. Admixtures/additives conforming to IS:6925 and IS:9103 may be used subjected to approval of the Engineer. However, admixers/additives generating Hydrogen or Nitrogen and containing Chlorides, Nitrates, Sulphides, Sulphates and any other material likely to adversely affect the steel or concrete shall not be permitted.

The general requirements for admixtures are given in Section 1012.

1706 SIZE OF COARSE AGGREGATES

The size (maximum nominal) of coarse aggregates for concrete to be used in various components shall be as given Table 1700-7.

Table 1700-7

Components	Maximum Nominal Size of Coarse Aggregate (mm)
i) RCC well curb	20
ii) RCC/PCC well steining	40
iii) Well cap or Pile Cap Solid type piers and abutments	40
iv) RCC work in girder, slabs wearing coat, kerb, approach slab, hollow piers and abutments, peir/abutment caps, piles	20
v) PSC Work	20
vi) Any other item	As specified by the Engineer

Maximum nominal size of aggregates shall also be restricted to the smaller of the following values :

a) 10 mm less than the minimum lateral clear distances between main reinforcements

b) 10 mm less than the minimum clear cover to the reinforcements

The proportions of the various individual size of aggregates shall be so adjusted that the grading produces densest mix and the grading curve corresponds to the maximum nominal size adopted for the concrete mix.

1707 EQUIPMENT

Unless specified otherwise, equipment for production, transportation and compaction of concrete shall be as under :

a) For Production of Concrete :

i) For overall bridge length of less than 200 m – bath type concrete mixer diesel or electric operated, with a minimum size of 200 litres, automatic water measuring system and integral with minimum (hydraulic/pneumatic type)

i) For overall bridge length of 200 m or more – concrete batching and mixing plant fully automatic with minimum capacity of 15 cu.m per hour.

All measuring devices of the equipment shall be maintained in a clean and serviceable condition. Its accuracy shall be checked over the range in use, when set up at each site and thereafter periodically as directed by the Engineer.

The accuracy of the measuring devices shall fall within the following limits :

Measurement of Cement	: 2 percent of the quantity of cement in each batch
Measurement of Water	: 3 percent of the quantity of water in each batch
Measurement of Aggregate	: 3 percent of the quantity of aggregate in each batch
Measurement of Admixture	: 3 percent of the quantity of admixture in each batch

b)	For Transportation concrete of		:	depending upon actual requirement
	i)	Concrete dumpers		minimum 2 tonnes capacity
	ii)	Powered hoists		minimum 0.5 tonne capacity
	ii)	Chutes		
	iii)	Buckets handled by cranes		
	iv)	Transit truck mixer		
	v)	Concrete pump		
	vi)	Concrete distributor booms		
	vii)	Belt conveyor		
	viii)	Cranes with skips		
	ix)	Tremies		
c)	For Compaction of Concrete		:	
	i)	Inter vibrators		size 25 mm to 70 mm
	ii)	Form vibrators		minimum 500 watts
	iii)	Screed vibrators		full width of carriageway (upto two lanes)

1708 MIXING CONCRETE

1708.1 Mixing at Site

Concrete shall be mixed either in concrete mixer or in a batching and mixing plant, as per these specifications. Hand mixing shall not be permitted. The mixer or the plant shall be at an approved location considering the properties of the mixes and the transportation arrangements available with the Contractor. The mixer or the plant shall be approved by the Engineer.

Mixing shall be continued till materials are uniformly distributed and a uniform colour of the entire mass is obtained, and each individual particle of the coarse aggregate shows complete coating of mortar containing its proportionate amount of cement. In no case shall mixing be done for less than 2 minutes. It shall be ensured that the mixers are not loaded above their rated capacities and shall be operated at a speed recommended by the Manufacturer.

Mixers which have been out of use of more than 30 minutes shall be thoroughly cleaned before putting in a new batch. Unless otherwise agreed to by the Engineer, the first batch of concrete from the mixer shall contain only two thirds of the normal quantity of coarse aggregate. Mixing plant shall be thoroughly cleaned before changing from one type of cement to another.

1708.2 Ready Mix Concrete

Ready mix concrete will be proportioned and mixed off the project site and delivered to the construction site in a freshly mixed and unhardened state, conforming to IS:4926 shall be allowed with the approval of the Engineer.

1708.3 Concreting Process

Once the concreting of a section is started, it has to be completed as a continuous operation. To ensure this, Contractor shall submit to the Engineer his programme backed with resources like availability of adequate equipments for batching, mixing, transporting and placing concrete prior to start of the concreting. Concreting of a section shall have to be done as a continuous operation to be completed within a reasonable time.

1709 TRANSPORTING, PLACING AND COMPACTION OF CONCRETE

The method of transporting and placing concrete shall be approved by the Engineer. Concrete shall be transported and placed as near as practicable to its final position, so that no contamination, segregation or loss of its constituent materials takes place. Concrete shall not be freely dropped into place from a height exceeding 2 m.

The equipment for transporting and placing concrete shall have means for discharging concrete without segregation.

When concrete is conveyed by chute, the plant shall be of such size and design as to ensure practically continuous flow. Slope of the chute shall be so adjusted that the concrete flows without excessive quantity of water and without any segregation of its ingredients. The delivery end of the chute shall be as close as possible to the point of deposit. The chute shall be thoroughly flushed with water before and after each working period and the water used for this purpose shall be discharged outside the formwork.

Placing Concrete with pumps :

Pipelines from the pump to the placing area shall be laid with minimum bends. For large quantity placements, standby pumps shall be available. Suitable air release valves, shutoff valves etc shall be provided as per the site requirements. The pumping of concrete shall precede pumping of priming mix i.e. rich mix of creamy consistency, to lubricate the concrete pump and pipelines. Continuous pumping shall be done to the extent possible. After concreting, the pipelines and accessories shall be cleaned immediately. A plug spung ball shall be inserted at the end near the pump and shall be forced through the pipeline by either water or by air pressure. The pipes for pumping shall not be made of material which have adverse effect on concrete. Aluminum alloy pipelines shall not be used.

All formwork and reinforcement contained in it shall be cleaned and made free from standing water, dust, snow or ice immediately before placing of concrete.

No concrete shall be placed in any part of the structure until the approval of the Engineer has been obtained.

If concreting is not started within 24 hours of the approval being given, it shall have to be obtained again from the Engineer. Concreting then shall proceed continuously over the area between the construction joints. Fresh concrete shall not be placed against concrete which has been in position for more than 30 minutes unless a proper construction joint is formed.

Except where otherwise agreed to by the Engineer, concrete shall be deposited in horizontal layers to a compacted depth of not more than 450 mm when internal vibrators are used and not exceeding 300 mm in all other cases.

Concrete when deposited shall have a temperature of not less than 5°C, and not more than 40°C. It shall be compacted in its final position within 30 minutes of its discharge from the mixer, unless carried in properly designed agitator, operating continuously, when this time shall be within 1 hour of the addition of cement to the mix and within 30 minutes of its discharge from the agitator. It may be necessary to add retarding admixtures to concrete if trials show that the periods indicated above are unacceptable. In all such matters, the Engineer's decision shall be final.

Concrete shall be thoroughly compacted by vibration or other means during placing and worked around the reinforcement, tendons or duct formers, embedded fixtures and into corners of the formwork to produce a dense homogeneous void-free mass having the required surface finish. When vibrators are used, vibration shall be done continuously during the lacing of each bath of concrete until the expulsion of air has practically ceased and in a manner that does not promote segregation. Over vibration shall be avoided to minimize the risk of forming a weak surface layer. When external vibrators are used, the design of formwork and disposition of vibrator shall be such as to ensure efficient compaction and to avoid surface blemishes. Vibrations shall not be applied through reinforcement and where vibrators of immersion type are used, contact with reinforcement and all inserts like ducts etc., shall be avoided. The internal vibrators shall be inserted in an orderly manner and the distance between insertions should be about one and half times the radius of the area visibly affected by vibration. Additional vibrators in serviceable condition shall be kept at site so that they can be used in the event of breakdown.

Mechanical vibrators used shall comply with IS:2502, IS:2506, IS:2514 and IS:4656.

1710 CONSTRUCTION JOINTS

Construction joints shall be avoided as far as possible and in no case the locations of such joints shall be changed or increased from those shown on the drawings, except with the express approval of the Engineer. The joints shall be provided in a direction perpendicular to the member axis.

Location, preparation of surface and concreting of construction joints shall conform to the additional specifications given in *Appendix 1700/I.*

1711 CONCRETING UNDER WATER

When it is necessary to deposit concrete under water, the methods, equipment, materials and proportions of mix to be used shall be got approved from the Engineer before any work is started. Concrete shall contain 10 percent more cement than that required for the same mix placed in the dry to compensate the loss due to wash.

Concrete shall not be placed in water having a temperature below 5°C. The temperature of the concrete, when deposited, shall not be less than 16°C, nor more than 40°C.

Coffer dams or forms shall be sufficiently tight to ensure still water conditions, if practicable, and in any case to reduce the flow of water to less than 3 m per minute through the space into which concrete is to be deposited. Coffer dams or forms in still water shall be sufficiently tight to prevent loss of mortar through the joints in the walls. Pumping shall not be done while concrete is being placed, or until 24 hours thereafter. To minimise the formation of laitance, care shall be exercised not to disturb the concrete as far as possible while it is being deposited.

All under water concreting shall be carried out by tremie method only, using tremie of appropriate diameter. The number and spacing of the tremies should be worked out to ensure proper concreting. The tremie concreting when started should continue without interruption for the full height of the member being concreted. The concrete production and placement equipment should be sufficient to enable the underwater concrete to be completed uninterrupted within the stipulated time. Necessary stand-by equipment should be available for emergency situation.

The top section of the tremie shall have a hopper large enough to hold one full batch of the mix or the entire contents of the transporting bucket as the case may be. The tremie pipe shall not be less than 200 mm in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of the water in which it is suspended, even if a partial vacuum develops inside the pipe. Preferably, flanged steel pipe of adequate strength for the job shall be used. A separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the

pipe is equipped with an approved automatic check valve, the upper end of the pipe shall be plugged with a wadding of gunny sacking or other approved material before delivering the concrete to the tremie pipe through the hopper so that when the concrete is forced down from the hopper to the pipe, it will force the plug (and along with it any water in the pipe) down the pipe and out of the bottom end, thus establishing a continuous stream of concrete. It will be necessary to raise slowly the tremie in order to allow a uniform flow of concrete, but it shall not be emptied so that water is not allowed to enter above the concrete in the pipe. At all times after placing of concrete is started and until all the required quantity has been placed, the lower end of the tremie pipe shall be kept below the surface of the plastic concrete. This will cause the concrete to build up from below instead of flowing out over the surface and thus avoid formation of layers of laitance. If the charge in the tremie is lost while depositing, the tremie shall be raised above the concrete surface and unless sealed by a check valve, is shall be replugged at the top end, as at the beginning, before refilling for depositing further concrete.

1712 ADVERSE WEATHER CONDITION

1712.1 Cold Weather Concreting

Where concrete is to be deposited at or near freezing temperature, precautions shall be taken to ensure that at the time of placing, it has a temperature of not less than 5°C and that the temperature of the concrete shall be maintained above 4°C until it has thoroughly hardened. When necessary, concrete ingredients shall be heated before mixing but cement shall not be heated artificially other than by the heat transmitted to it from other ingredients of the concrete. Stock-piled aggregate may be heated by the use of dry heat or steam. Aggregates shall not be heated directly by gas or on sheet metal over fire. In general, the temperature of aggregates or water shall not exceed 65°C. Salt or other chemicals shall not be used for the prevention of freezing. No frozen material or materials containing ice shall be used. All concrete damaged by frost shall be removed. Concrete exposed to freezing weather shall have entrained air and the water content of the mix shall not exceed 30 litres per 50 kg of cement.

1712.2 Hot Weather Concreting

When depositing concrete in hot weather, precautions shall be taken so that the temperature of wet concrete does not exceed 40°C while placing. This shall be achieved by stacking aggregate under the shade and keeping them moist, using cold water, reducing the time between mixing and placing to the minimum, cooling formwork by sprinkling water, starting curing before concrete dries out and restricting concreting as far as possible to early mornings and later evenings. When ice is used to cool mixing water, it will be considered a part of the water in design mix. Under no circumstances shall the mixing operation be considered complete until all ice in the mixing drum has melted.

The Contractor will be required to state his methodology for the Engineer's approval when temperatures of concrete are likely to exceed 40^{o}C during the work.

1713 PROTECTION AND CURING

Concreting operations shall not commence until adequate arrangements for concrete curing have been made by the Contractor.

Curing and protection of concrete shall start immediately after compaction of the concrete to protect it from :

a) Premature drying out particularly by solar radiation and wind

b) High internal thermal gradients

c) Leaching out by rain and flowing water

d) Rapid cooling during the first few days after placing

e) Low temperature or frost

f) Vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement

Where members are of considerable size and length, with high cement content, accelerated curing methods may be applied, as approved by the Engineer.

1713.1 Water Curing

Water for curing shall be as specified in Section 1000.

Sea water shall not be used for curing. Sea water shall not come into contact with concrete members unless it has attained adequate strength.

The concrete should be kept constantly wet for a minimum period of 14 (fourteen) days after concreting except for rapid hardening cement concrete where it can be reduced to 5 (five) days. Water should be applied on surfaces after the final set. Curing through watering shall not be done on green concrete. On formed surfaces, curing shall start immediately after the forms are stripped. The concrete shall be kept constantly wet by ponding or covered with a layer of sacking, canvas, hessian or a similar absorbent material.

After placing and during the first stages of hardening concrete shall be protected from harmful effects of sunrays, drying winds, cold, running water, shocks, vibrations, traffic including construction traffic etc.

1713.2 Steam Curing

Where steam curing is adopted, it shall be ensured that it is done in suitable enclosure to contain the live steam in order to minimize moisture and heat losses. The initial application of the steam shall be after about four hours of placement of concrete to allow the initial set of the concrete to take place.

Where retarders are used, the waiting period before application of the steam shall be increased to about six hours.

The steam shall be at 100 percent relative humidity to prevent loss of moisture and to provide excess moisture for proper hydration of the cement. The application of steam shall not be directly on the concrete and the ambient air temperature shall increase at a rate not exceeding 5^{o}C per hour until a maximum temperature of 60^{o}C to 70^{o}C is reached. The maximum temperatures shall be maintained until the concrete has reached the desired strength.

When steam curing is discontinued, the ambient air temperature shall not drop at a rate exceeding 5^{o}C per hour until a temperature of about 10^{o}C above the temperature of the air to which the concrete will be exposed, has been reached.

The concrete shall not be exposed to temperatures below freezing for at least six days after curing.

1713.3 Curing Compound

Membrane forming curing compounds consisting of waxes, resins, chlorinated rubbers etc. may be permitted by the Engineer in special circumstances. Curing compounds shall not be used on any surface which requires further finishing to be applied. All construction joints shall be moist, cured and no curing compound shall be permitted in locations where concrete surfaces are required to be bonded together.

Curing compounds shall be continuously agitated during use. All concrete cured by this method shall receive two applications of the curing compound. The first coat shall be applied immediately after acceptance of concrete finish. If the surface is dry, the concrete shall be saturated with water and curing compound applied as soon as the surface film of water disappears. The second application shall be made after the first application has set. Placement in more than two coats may be required to prevent streaking.

1714 FINISHING

Immediately after the removal of forms, exposed bars or bolts, if any, shall be cut inside the concrete member to a depth of at least 50 mm below the surface of the concrete and the

resulting holes filled by the removal of form ties and all other holes and depressions, honeycomb spots, broken edges or corners, and other defects, shall be thoroughly cleaned, saturated with water and carefully pointed and rendered true with mortar of cement and fine aggregate mixed in the proportions used in the grade of concrete that is being finished and of as dry as consistency as is possible to use. Considerable pressure shall be applied in filling and pointing to ensure thorough filling in all voids. Surfaces which have been pointed shall be kept moist for a period of twenty four hours. Special pre-packaged proprietary mortars shall be used where appropriate or where specified in the drawing.

All construction and expansion joints in the completed work shall be left carefully tooled and free from any mortar and concrete. Expansion joint filler shall be left exposed for its full length with clean and true edges.

Immediately on removal of forms, the concrete work shall be examined by the Engineer before any defects are made good.

a) The work that has sagged or contains honeycombing to an extent detrimental to structural safety or architectural appearance shall be rejected.

b) Surface defect of a minor nature may be accepted. On acceptance of such work by the Engineer, the same shall be rectified as directed by the Engineer.

1715 TOLERANCES

Tolerances for dimensions/shape of various components shall be as indicated in these specifications or shown on the drawings or as directed by the Engineer.

1716 TESTS AND STANDARDS OF ACCEPTANCE

1716.1 Concrete shall conform to the surface finish and tolerance as prescribed in these Specifications for respective components.

1716.2 Random sampling and lot by lot of acceptance inspection shall be made for the 28 days cube strength of concrete.

1716.2.1 Concrete under acceptance shall be notionally divided into lots for the purpose of sampling, before commencement of work. The delimitation of lots shall be determined by the following :

i) No individual lot shall be more than 30 cu.m in volume

ii) At least one cube forming an item of the sample representing the lot shall be taken from concrete of the same grade and mix proportions cast on any day.

iii) Different grades of mixes of concrete shall be divided into separate lots.

iv) Concrete of a lot shall be used in the same identifiable component of the bridge.

1716.2.2 Sampling and testing

i) Concrete for making 3 test cubes shall be taken from a batch of concrete at point of delivery into construction, according to procedure laid down in IS:1199.

ii) A random sampling procedure to ensure that each of the concrete batches forming the lot under acceptance inspection has equal chance of being chosen for taking cubes shall be adopted.

iii) 150 mm cubes shall be made, cured and tested at the age of 28 days for compressive strength in accordance with IS:516. The 28 day test strength result for each cube shall form an item of the sample.

1716.2.3 Test specimen and sample strength : Three test specimens shall be made from each sample for testing at 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7 days or for any other purpose.

The test strength of the sample shall be the average of the strength of 3 cubes. The individual variation should not be more than + 15 percent of the average. If variation is more, the test results of the sample are invalid.

1716.2.4 Frequency : The minimum frequency of sampling of concrete of each grade shall be in accordance with Table 1700-8

Table 1700-8

Quantity of Concrete in work, m^3	No. of samples
1 – 5	1
6 – 15	2
16 – 30	3
31 – 50	4
51 and above	4 plus one additional sample for each additional 50 m^3 or part thereof

At least one sample shall be taken from each shift of work.

1716.2.5 Acceptance criteria

When both the following conditions are met, the concrete complies with the specified compressive strength:

a) The mean strength determined from any group of four consecutive samples should exceed the specified characteristic compressive strength.

b) Strength of any sample is not less than the specified characteristic compressive strength minus 3 MPa.

When the concrete does not satisfy both the above conditions, cores shall be extracted from the representative hardened concrete. Area for compression test in accordance with the method described in IS:1199 and tested whether the concrete satisfies the compressive strength.

The quantity of concrete represented by the test results include the batches from which the first and last samples were taken, together with all intervening batches.

Chloride and Sulphate Content

The total chloride and sulphuric anhydride (SO_3) content of all the constituents of concrete as a percentage of mass of cement in the mix shall not exceed the values given in this section of the Specifications.

1716.3 Density of Fresh Concrete

Where minimum density of fresh concrete is specified, the mean of any four consecutive samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 percent of the specified value.

1716.4 Density of Hardened Concrete

Where minimum density of hardened concrete is specified, the mean of any four consecutive samples shall not be less than the specified value and any individual sample result shall not be less than 97.5 percent of the specified value.

1716.5 Permeability Test

The concrete should pass the following test if it is properly compacted and is not considered permeable :

i) Prepare a cylindrical test specimen 150 mm dia and 150 mm high.

ii) After 28 days of curing, the test specimen is fitted in a machine such that the specimen can be placed in water under pressure upto 7 bars. A typical machine is shown in *Appendix 1700/II.*

iii) At first a pressure of one bar is applied for 48 hours, followed by 3 bars for 24 hours and 7 bars for next 24 hours.

iv) After application of pressure of the above period, the specimen is taken out and split in the middle by compression applied on two round bars on opposite sides above and below.

v) The water penetration in the broken core is to be measured with a scale and the depth of penetration assessed in mm (max. permissible limit 25 mm).

1716.6 If the concrete is not able to meet any of the standards of acceptance as prescribed, the effect of such deficiency on the structure shall be investigated by the Contractor as directed by the Engineer. The Engineer may accept the concrete as sub-standard work. Any additional work required by the Engineer for such acceptance shall be carried out by the Contractor at his cost. In case the concrete is not found to be acceptable after investigation, the Contractor shall remove the rejected concrete forthwith.

1717 MEASUREMENTS FOR PAYMENT

Structural concrete shall be measured in cubic metres. In reinforced or prestressed concrete, the volume occupied by reinforcement or prestressing cables and sheathing shall not be deducted. The slab shall be measured as running continuously through and the beam as the portion below the slab.

1718 RATE

The contract unit rate for structural concrete shall cover costs of all materials, labour, tools, plant and equipment required for mixing, transporting and placing in position, vibrating and compacting, finishing and curing as per this Section or as directed by the Engineer, including all incidental expenses, sampling and testing, quality assurance and supervision. Unless mentioned separately as an item in the Contract, the contract unit rate for concrete shall also include the cost of providing, fixing and removing formwork required for concrete work as per Section 1500.

Where concrete is found to be acceptable as by the Engineersub-standard work, the Contractor shall be subjected to reduction in his contact unit rate. For deficiency in compressive strength of concrete when accepted by the Engineer, the reduction in rate shall be applied as under

$$\text{Per cent reduction} = \frac{\text{Design Strength - Observed Strength}}{\text{Design Strength}} \times 1000$$

1800

Prestressing

1801 DESCRIPTION

Structural concrete containing prestressed steel reinforcement to introduce precompression is termed as prestressed concrete.

The work shall be carried out in accordance with the drawings and these Specifications or as approved by the Engineer.

Concrete and untensioned steel for the construction of prestressed concrete members shall conform to the requirements of sections 1700 and 1600 for Structural Concrete and Steel Reinforcement respectively in so far as the requirements of these Sections apply and are not specifically modified by requirements set forth herein.

1802 MATERIALS

1802.1 All materials shall conform to Section 1000.

1802.2 Sheathing

1802.2.1 The sheathing ducts shall be of the spiral corrugated type either in mild steel or in HDPE. They shall be in as long lengths as practical from handling and transportation considerations without getting damaged.

M.S. Sheathing ducts

The material shall be Cold Rolled Cold Annealed (CRCA) Mild Steel conforming to IS:513 intended for mechanical treatment and surface refining but not for quench hardening or tempering.

The material shall be clean and free from rust and normally be bright finished. However, where specified, as in case of use in aggressive environment, galvanized or lead-coated mild steel strips shall be used.

The thickness of sheathing shall be as shown on the drawing, but shall not be less than 0.3 mm, 0.4 mm and 0.5 mm for sheathing ducts having internal diameter of 50 mm, 75 mm and 90 mm respectively. For larger diameter of ducts, thickness of sheathing shall be based on recommendations of prestressing system supplier or as directed by the Engineer.

The sheathing shall conform to the requirement specified in Appendix 1A of IRC:18. All the joints of sheathing shall be water tight and conform to provisions contained in Appendix 2 of IRC:18.

Corrugated HDPE sheathing ducts

The material for the ducts shall be high-density polyethylene withmore than 2 percent carbon black to provide resistance to ultraviolet degradation and shall have the following properties:

Specific Density	:	*0.954 g/cm^3 at 23^{0}C*
Yield Strength	:	*18.0 N/mm^2*
Tensile Strength	:	*21.0 N/mm^2*
Shore Hardness D-3 sec. value	:	*60*
-15 sec. value	:	*58*
Notch impact strength at 23^{0}C	:	*10 kJ/m^2*
-40^{0}C	:	*4 kJ/m^2*
Coefficient of Thermal Expansion for 20^{0}C – 80^{0}C	:	*1.50 x 10^{-4} kJ/m^2*

The thickness of the wall shall be 2.3+ 0.3 mm as manufactured and 1.5 mm after loss in the compression test, for duct size upto 160 mm OD.

The ducts shall be corrugated on both sides. The ducts shall transmit full tendon strength from the tendon to the surrounding concrete over a length not greater than 40 duct diameters.

These ducts shall be joined by adopting any one or more of the following methods, as convenient to suit the individual requirements of the location, subject to the satisfactory pressure tests before adoption.

Screwed together with male and female threads.

Joining with thick walled HDPE shrink couplers with glue. This can also be used for connection with trumpet etc.

Welding with electrofusion couplers.

The joints shall be able to withstand an internal pressure of 0.5 bar for 5 minutes as per test procedure given in Appendix II of IRC:18.

For major projects, the sheathing duct should preferably be manufactured at the project site utilizing appropriate machines. With such an arrangement, long lengths of sheathing ducts may be used with consequent reduction in the number of joints and couplers. Where sheathing duct joints are unavoidable, such joints shall be made slurry tight by the use of corrugated threaded sleeve couplers which may be tightly screwed onto the outer side of the sheathing ducts.

The length of the coupler should not be less than 150 mm but should be increased upto 200 mm wherever practicable. The joints between the end of coupler and duct shall be sealed with heat shrink tape to prevent penetration of slurry during concreting. The couplers of adjacent ducts shall be staggered wherever practicable. As far as possible, couplers should not be located in curved zones. The corrugated sleeve couplers are being conveniently manufactured using the sheath making machine with the next higher size of die set.

1802.2.2 The internal area of the sheathing duct shall be in accordance with the recommendations of the system manufacturer and shall be about three times the area of the tendons. In case of 6T13, 12T13 and 19T13 size of tendons comprising 12/13 mm dia strands, the inner diameter of the sheathing shall not be less than 50 mm, 75 mm and 90 mm respectively or those shown in the drawing, which ever is greater.

Where prestressing tendons are required to be threaded after concreting, a temporary tendon shall be inserted in the sheathing or the sheathing shall be stiffened by other suitable method during concreting.

1802.3 Anchorages

1802.3.1 Prestressing accessories like jacks, anchorage, wedge, block plate, etc. being patended items shall be procured from authorized manufacturers only. Anchorages shall conform to BS:4447. The prestressing accessories shall be subjected to an acceptance test prior to their actual use on the work. Test certificates from a laboratory fully equipped to carry out the tests shall be furnished to the Engineer. Such test certificates shall not be more than 12 months old at the time of making the proposal for adoption of a particular system for the project.

No damaged anchorages shall be used. Steel parts shall be protected from corrosion at all times. Threaded parts shall be protected by greased wrappings and tapped holes shall be protected by suitable plus until used. The anchorage components shall be kept free from mortar and loose rust and any other deleterious coating.

1802.3.2 Swages of prestressing strand and button-heads of prestressing wire, where provided shall develop a strength of at least 95 percent of the specified breaking load of the strand or wire as the case may be. Where swaging/button-heading is envisaged, the Contractor shall furnish details of his methodology and obtain approval of the Engineer, prior to his taking up the work.

1802.3.3 Untensioned steel reinforcements, around anchorages shall conform to the details of prestressing system and as shown on the drawing.

1802.4 Couplers

Coupling units and other similar fixtures used in conjunction with the prestressing strands or bars shall have an ultimate tensile strength of not less than the individual strengths of the strands or bars being joined.

1803 TESTING OF PRESTRESSING STEEL AND ANCHORAGES

All materials specified for testing shall be furnished free of cost and shall be delivered in time for tests to be made well in advance of anticipated time of use.

All wire, strand or bars to be shipped to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be shipped shall be like-wise identified.

All samples submitted shall be representative of the lot to be furnished and in the case of wire or strand, shall be taken from the same master roll. The Contractor shall furnish samples of at least 5.0 m in length selected from each lot for testing. Also, two anchorage assemblies, complete with distribution plates of each size or types to be used, shall be furnished alongwith short lengths of strands as required.

1804 WORKMANSHIP

1804.1 Cleaning

Tendons shall be free from loose rust, oil, grease, tar, paint, mud or any other deleterious substance.

Cleaning of the steel may be carried out by immersion in suitable solvent solutions, wire brushing or passing through a pressure box containing carborundum powder. However, the tendons shall not be brought to a polished condition.

1804.2 Straightening

High tensile steel wire and strand shall be supplied in coils of sufficiently large diameter such that tendons shall retain their physical properties and shall be straight as it unwinds from the coil. Tendons of any type that are damaged, kinked or bent shall not be used.

The packing of prestressing wire/strand shall be removed only just prior to making of cable for placement. Suitable stands shall be provided to facilitate uncoiling of wires/strands

without damage to steel. Care shall be taken to avoid the possibility of steel coming into contact with the ground.

1804.3 Positioning

1804.3.1 Post-Tensioning

Prestressing tendons shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.

Tendons shall be so arranged that they have a smooth profile without sudden bends or kinks.

The locationing of prestressed cables shall be such as to facilitate easy placement and vibration of concrete in between the tendons. High capacity tendon shall be used to reduce the number of cables thereby eliminating the necessity of grouping. The selected profiles of the tendons shall be such that their anchorages are not located in the top deck surface. Where two or more rows of cables have to be used, the cables shall be vertically in line to enable easy flow. Two cables shall in no case be less than 100 mm anywhere along the length of the superstructure. Where precast segments are used, the clear distance shall be at least 150 mm.

Sheathing shall be placed in correct position and profile by providing suitable ladders and spacers. Such ladders may be provided at intervals of approximately 1.0 m. Sheathing shall be tied rigidly with such ladders/spacer bars so that they do not get disturbed during concreting.

The method of supporting and fixing shall be such that profile of cables is not disturbed during vibrations, by pressure of wet concrete, by workmen or by construction traffic.

Sheathing in which the permanent tendon will not be in place during concreting shall have a temporary tendon inserted or shall be stiffened by some other method to the approval of the Engineer. The temporary tendon shall be pulled out before threading the permanent tendon into place by a special threading machine or other contrivance.

Where possible tendons shall not be placed until immediately prior to stressing. Tendons shall be handled with care to avoid damage or contamination, to either the tendon or the sheathing. Any tendons damaged or contaminated shall be cleaned or replaced.

1804.3.2 Pre-Tensioning : Prestressing steel shall be accurately located and maintained in position, both vertically and horizontally, as per drawings.

1804.3.3 Each anchorage device shall be set square to the line of action of the corresponding prestressing tendon and shall be positioned securely to prevent movement during concreting.

The anchorage devices shall be cleaned to the satisfaction of the Engineer prior to the placing of concrete. After concreting, any mortar or concrete which adheres to bearing or wedging surfaces, shall be removed immediately.

1804.4 Cutting

Cutting and trimming of wires or strands shall be done by suitable mechanical or flame cutters. When a flame cutter is used, care shall be taken to ensure that the flame does not come in contact with other stressed steel. The location of flame cutting of wire or strand shall be kept beyond 75 mm of where the tendon will be gripped by the anchorage or jacks.

In post-tensioning the ends of prestressing steel projecting beyond the anchorages, shall be cut after the grout has set.

1804.5 Protection of Prestressing Steel

Prestressing steel shall be continuously protected against corrosion, until grouted. The corrosion protector shall have no deleterious effect on the steel or concrete or on the bond strength of steel to concrete. Grouting shall conform to these Specifications or as directed by the Engineer.

In the case of external prestressing, steel shall be encased in suitable polyethelene pipes before grouting.

1804.6 Sheathing

The joints of all sheathings shall be water-tight. Special attention shall be paid to the junction at the anchorage end, where the sheathing must tightly fit on the protruding trumpet end of anchorage and thereafter sealed preferably with heat shrink tape, to make it water-proof.

The heat-shrink tape is supplied in the form of bandage rolls which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after heating the bandage material shrinks on the sheathing duct and ensures formation of a leak-proof joint. The heating is effected by means of a soft gas flame.

A sheath making machine should be positioned at the site of work for large projects so that sheathing can be prepared as and when it is required for construction.

The sheathing and all joints shall be water tight. Any temporary opening in the sheathing shall be satisfactorily plugged and all joints between sheathing and any other part of the prestressing system shall be effectively sealed to prevent entry of mortar, dust, water or other deleterious matter. Sheathing shall be neatly fitted at joints without internal projection or reduction of diameter.

Enlarged portions of the sheathing at couplings or anchorages shall be of sufficient length to provide for the extension of the tendons.

1804.7 Grout Vents

Grout vents of at least 20 mm diameter shall be provided at both ends of the sheathing and at all valleys and crests along its length. Additional vents with plugs shall also be provided along the length of sheathing such that the spacings of consecutive vents do not exceed 20 m. Each of the grout vents shall be provided with a plug or similar device capable of withstanding a pressure of 1.0 MPa without the loss of water, air pressure or grout.

1804.8 Anchorages

All bearing surfaces of the anchorages shall be cleaned prior to concreting and tensioning.

Anchor cones, blocks and plates shall be securely positioned and maintained during concreting such that the center line of the duct passes axially through the anchorage assembly.

The anchorages shall be recessed from the concrete surface by a minimum cover of 100 mm.

After the prestressing operations are completed and prestressing wires/strands are cut, the surface shall be painted with two coats of epoxy of suitable formulation having a dry film thickness of 80 micron per coat and entire recess shall be filled with concrete or non-shirk/pre-packaged mortar of epoxy concrete.

1804.9 Structural Concrete

Structural concrete shall conform to Section 1700. The formwork shall conform to Section 1500.

1805 SUPERVISION

Pre-stressing operation and grouting shall be entrusted to only specially trained and qualified personnel. All pre-stressing accessories shall be procured from authorized manufacturers with in-house testing facilities. The Contractor shall also be required to engage specialized

agencies who should also be entrusted with the total service contract for fabrication of cables, protection of cables during concreting, pre-stressing and grouting. Necessary certificates shall also be accorded by such specialized agencies that the work has been carried out in accordance with prescribed specifications. In exceptional cases where the employer is convinced that the Contractor of the bridge itself is well experienced and has qualified personnel and sufficient track record to substantiate his performance in the particular system of pre-stressing being adopted, the pre-stressing and grouting operations could be entrusted to the contractor.

1806 TENSIONING EQUIPMENT

All tensioning equipment shall be procured from authorized manufacturers only and be approved by the Engineer prior to use. Where hydraulic jacks are used, they shall be power-driven unless otherwise approved by the Engineer. The tensioning equipment shall satisfy the following requirements :

i) The means of attachments of the prestressing steel to the jack or any other tensioning apparatus shall be safe and secure.

ii) Where two or more wires/strands constitute a tendon, a single multipull stressing jack shall be used which is capable of tensioning simultaneously all the wires/strands of the tendon. Suitable facilities for handling and attaching the multipull jack to the tendons shall be provided.

iii) The tensioning equipment shall be such that it can apply controlled total force gradually on the concrete without inducing dangerous secondary stressed in steel, anchorage or concrete; and

iv) Means shall be provided for direct measurement of the force by use of dynamometers or pressure gauges fitted in the hydraulic system itself to determine the pressure in the jacks. Facilities shall also be provided for the liner measurement of the extension of prestressing steel to the nearest mm and of any slip of the gripping devices at transfer.

All dynamo meters and pressure gauges including a master gauge shall be calibrated by an approved laboratory immediately prior to use and then at intervals not exceeding 3 months and the true force determined from the calibration curve.

Pressure gauges shall be concentric scale type gauges accurate to within two per cent of their full capacity. The minimum nominal size of gauge shall be 100 mm. The gauge shall be so selected that when the tendon is stressed to 75 percent of its breaking load, the gauge is reading between 50 percent and 80 percent of its full capacity. Suitable safety devices shall be fitted to protect pressure gauges against sudden release of pressure.

Provision shall be made for the attachment of the master gauge to be used as a check whenever requested for by the Engineer.

Jack & pump shall be calibrated from an approved laboratory prior to use and then at intervals not exceeding three months.

1807 POST-TENSIONING

Tensioning force shall be applied in gradual and steady steps and carried out in such a manner that the applied tensions and elongations can be measured at all times. The sequence of stressing, applied tensions and elongations shall be in accordance with the approved drawing or as directed by the Engineer.

It shall be ensured that in no case, the load is applied to the concrete before it attains the strength specified on the drawing or as stipulated by the prestressing system supplier, whichever is more.

After prestressing steel has been anchored, the force exerted by the tensioning equipment shall be decreased gradually and steadily so as to avoid shock to the prestressing steel or anchorage.

The tensioning force applied to any tendon shall be determined by direct reading of the pressure gauges or dynamo-meters and by comparison of the measured elongation with the calculated elongation. The calculated elongation shall be invariably adjusted with respect to the modulus of elasticity of steel for the particular lot as given by the manufacturer.

The difference between calculated and observed tension and elongation during prestressing operations shall be regulated as follows :

a) If the calculated elongation is reached before the specified gauge pressure is obtained, continue tensioning till attaining the specified gauge pressure, provided the elongation does not exceed 1.05 times the calculated elongation. If 1.05 times the calculated elongation is reached before the specified gauge pressure is attained, stop stressing and inform the Engineer.

b) If the calculated elongation has not been reached at the specified gauge pressure, continue tensioning by intervals of 5kg/sq. cm until the calculated elongation is reached provided the gauge pressure does not exceed 1.05 times the specified gauge pressure.

c) If the elongation at 1.05 times the specified gauge pressure is less than 0.95 times the calculated elongation, the following measures

must be taken, in succession, to determine the cause of this lack of discrepancy :

i) Check the correct functioning of the jack, pump and leads.

ii) De-tension the cable. Slide it in its duct to check that it is not blocked by mortar which has entered through holes in the sheath. Re-tension the cable if free.

iii) Re-establish the modulus of elasticity of steel for the particular lot from an approved laboratory.

If the required elongation is still not obtained, further finishing operations such as cutting or sealing, should not be undertaken without the approval of the Engineer.

d) When stressing from one end only, the slip at the end remote from the jack shall be accurately measured and an appropriate allowance made in the measured extension at the jacking end.

A complete record of prestressing operations along with elongation and jack pressure data shall be maintained in the format given in *Appendix 1800/II*. The number of stages of prestressing and grouting shall be reduced to a minimum, preferably two in the case of simply supported girders.

1808 GROUTING OF PRESTRESSED TENDONS

Grouting material and operation shall conform to *Appendix 5 of* IRC:18.

1809 PRE-TENSIONING

1809.1 General

The planning and construction aspects of the tensioning bed, tensioning bench, abutments at location of anchorage, steam curing system, formwork of the concrete elements and arrangements for de-moulding, lifting, stacking and transportation of the pre-tensioned concrete elements are all specialised items and shall be entrusted to engineers specifically experienced in this type of work.

1809.2 Stressing Bed for Pre-tensioning

The abutments and bed for pre-tensioning of tendons shall be designed to withstand the total tensioning force.

A notice shall be displayed adjacent to the stressing bed showing the maximum tensioning force permitted.

Where concrete elements are cast and prestressed individually, the stressing bench or moulds shall be rigid enough to sustain the reaction of the prestressing force without distortion.

In the long line method of prestressing, sufficient locator plates should be distributed throughout the length of the bed to ensure that the wires are maintained in their proper position during concreting. The moulds shall be free to slide in the direction of their length and thus permit the transfer of the prestressing force to all the concrete elements along the whole line.

Sufficient space shall be left in between the ends of concrete elements to permit access for cutting the strands/wires after transfer. Hold-downs or deflectors shall be used for holding or deflecting the tendons in required position firmly. Deflectors which are in contact with the tendon shall have a diameter not less than the tendon or 15 mm, whichever is more.

The tensioning force required to be applied as stated on the drawings shall be the force remaining in the strands/wires after all strands/wires have been anchored to the abutments of the stressing bed and after the anchorage slip has already taken place. The tensioning force shall be determined by direct reading of the pressure gauges or dynamo-meters and by the measured elongation after slip.

The Contractor shall submit method of tensioning the tendons including the arrangement and layout of prestressing beds and all tendon deflection points to the Engineer for approval before manufacture commences.

The Contractor shall carry out trial stressing operations to establish the frictional resistance offered by the hold-downs and the slip during anchoring.

Where sheathing of pre-tensioned tendons is required to prevent bond over a specified length, it shall consist of plastic tubing or other material approved by the Engineer and shall be of a quality, diameter and thickness such that bond shall be effectively prevented. The tubing shall be fastened to the tendon in such a manner that cement mortar cannot enter. The Engineer may order that the pull-in of the tendon be measured during the transfer of prestress.

The Contractor shall also submit calculation showing that the hold-downs have been designed and constructed to withstand concentrated loads resulting from the application of the tensioning force.

1809.3 Tensioning Procedure

The tensioning of the wires and strands shall be done not too much in advance of concreting.

The tensioning force shall be applied gradually and uniformly.

In order to remove slack and to lift tendons off the bed floor, an initial force approved by the Engineer shall be applied to the tendons. Allowance shall be made for this force in calculating the required elongation.

Tendons shall be marked for measurement of elongation after the initial force has been applied. When required by the Engineer, tendons shall be marked at both the jacking end and dead end of the stressing bed and at couplers if used so that slip and draw-in may be measured.

Where deflected strands have been specified, the Engineer may direct the elongation or strain gauge measurements be taken at various positions along the tendon to determine the force in the tendon at those positions.

1809.4 Transfer of Prestress

While the process of tensioning can be accomplished by means of hydraulic jacks, some positive mechanical means shall be provided to maintain the tension during the entire period between the tensioning of the wires/strands and transfer of the prestressing force to the concrete element.

Transfer of prestress shall not proceed until the Engineer has approved the proposed method. Tendons and deflection devices shall be released in such a pre-determined order that unacceptable tensile stresses are not induced in the concrete.

Prior to transfer of the force to the units, all tendons shall be tested for tightness and any loose tendon shall be reported to the Engineer who will decide whether the units affected shall be rejected.

The Engineer may require that tendons be marked at each end of any unit to allow measurement of the pull-in of the concrete.

Tendons shall be released gradually and preferably simultaneously.

Under no circumstances shall tendons be cut while under tension.

On completion of the transfer of prestress, the projecting lengths of tendon shall be cut off flush with the end surface of the unit, unless otherwise shown, by a method approved by the Engineer.

In no case shall the transfer of prestressing force to the concrete elements take place before concrete attains the strength specified in the drawings. To determine the specified

strength, additional cube testing shall be undertaken at the Contractor's cost. in case steam curing is employed, the cubes shall be placed in the same environment as the concrete elements to obtain an accurate assessment of concrete strength at the time of transfer.

The sequence of transfer of prestressing force shall be done strictly as indicated in the drawings and ensuring that eccentricities of the prestressing force in the vertical and horizontal directions of the concrete element are minimum during the entire sequence.

The maximum slip of any tendon during transfer shall not exceed 3 mm at any end of the concrete element. In case this slip is exceeded, the concrete element in question shall be rejected.

1809.5 Protection of Ends

The exposed ends of the tendons and the concrete surfaces of the ends of the units shall be wire brushed clean of all rust, loose mortar, grease and dirt.

The exposed ends of the tendons and concrete surface within 50 mm of tendons shall be then abraded to provide a clean sound surface. An epoxy tar paint suitably formulated to give a dry film thickness of 80 micron per coat shall then be immediately applied over the ends of the tendons unless otherwise directed.

A second coat of paint shall be applied prior to the drying out of the first coat.

1810 SAFETY PRECAUTIONS DURING TENSIONING

Care shall be taken during tensioning to ensure the safety of all persons in the vicinity.

Jacks shall be securd in such a manner that they will be held in position, should they lose their grip on the tendons.

No person shall be allowed to stand behind the jacks or closed to the line of the tendons while tensioning is in progress.

The operations of the jacks and the measurement of the elongation and associated operations shall be carried out in such a manner and from such a position that the safety of all concerned is ensured.

A safety barrier shall be provided at both ends to prevent any tendon, which might become loose from recoiling unchecked.

During actual tensioning operation, warning signs shall be displayed at both ends of the tendon.

After prestressing, concrete shall neither be drilled nor any portion cut nor chipped away nor disturbed, without express approval of the Engineer.

No welding shall be permitted on or near tendons nor shall any heat be applied to tendons. Any tendon which has been affected by welding, weld spatter or heat shall be rejected.

1811 TRANSPORTATION AND STORAGE OF UNITS

Precast girders shall be transported in an upright position. Points of support and the direction of reactions with respect to the girder shall approximately be the same during transportation, and storage as when the girder is placed in final position.

When members are to be stacked, they shall be firmly supported at such bearing positions as will ensure that the stresses induced in them are always less than the permissible design stresses. Further, inclined side supports shall be provided at the ends and along the length of a precast girder to prevent lateral movements or instability.

Care shall be taken during storage, hoisting and handling of the precast units to prevent their cracking or being damaged. Any unit damaged by improper storing or handling shall be replaced by the Contractor at his cost.

1812 TOLERANCES

Permissible tolerances for positional deviation of Prestressing tendons shall be as under:

a) Variation from the specified horizontal profile : 5 mm

b) Variation from the specified vertical profile : 5 mm

c) Variation from the specified position in member : 5 mm

1813 TESTS AND STANDARDS OF ACCEPTANCE

The material shall be tested in accordance with these Specifications and shall meet the prescribed criteria and requirements

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

1814 MEASUREMENTS FOR PAYMENT

Prestressed Concrete shall be measured in cubic metres. The volume occupied by mild steel reinforcement / HYSD bars, high tensile steel, sheathing and anchorages shall not be deducted.

High tensile (prestressing) steel shall be paid for separately and its length shall be measured as actually incorporated in the finished work.

From the length so measured its weight shall be calculated in tonnes on theoretical basis and paid.

Anchorage devices, additional length of cables for attaching jack, ducts or sheathing, grout, non-prestressed steel reinforcement fixed to the anchorage devices, making of recesses and filling the same, protection by painting with epoxy and furnishing samples for testing shall all be deemed to be included in the item of high tensile steel and shall not be measured separately.

1815 RATE

The contract unit rate for cast-in-place prestressed concrete shall cover the cost of all materials, labour, tools and plant required for mixing, placing in position, vibrating and compacting, finishing as per directions of the Engineer, curing and other incidental expenses for producing concrete of specified strength to complete the structure or its components as shown on the drawings and according to Specifications. The contract unit rate shall also include the cost of making, fixing and removing of all centering and formwork required for the work unless otherwise specified in the Contract.

For precast prestressted concrete members, the unit rate, in addition to above, shall also include the cost of all materials, labour, tools and plant required to transport and place these members in their final position as shown on the drawings and as directed by the Engineer.

The contract unit rate for high tensile steel shall cover the cost of material, labour, tools and plant required for manufacturing, placing, tensioning, anchoring and grouting the high tensile steel in the prestressed concrete as shown on the drawings and as per Specifications herein above or as directed by the Engineer.

The cost of anchorage devices, additional length of cables for attaching jack, ducts or sheathing, grout, non-prestressed steel reinforcement fixed to the anchorage devices, making of recesses and filling the same, protection by painting with epoxy and furnishing samples for testing shall all be included in the unit rate. Rate shall also include payments if any to be made to the supplier of the prestessing system who has to monitor, ensure and certify the correctness of all operations.

1900

Structural Steel

1901 DESCRIPTION

This work shall include furnishing, fabricating, transporting, erecting and painting structural steel, rivet steel, cast steel, steel forgings, cast iron and other incidental metal construction of the kind, size and quantity in conformity with the drawings and these specifications or as directed by the Engineer.

1902 GENERAL

General requirements relating to the supply of material shall conform to the specifications of IS:1387, for the purpose of which the supplier shall be the Contractor and the purchaser shall be the Engineer.

Finished rolled material shall be free from cracks, flaws, injurious seams, laps, blisters, ragged and imperfect edges and other defects. It shall have a smooth and uniform finish, and shall be straightened in the mill before shipment. They shall also be free from loose mill scale, rust, pits or other defects affecting its strength and durability.

The acceptance of any material on inspection at the mill i.e. rolling mills foundry or fabricating plant where material for the work is manufactured, shall not be a bar to its subsequent rejection, if found defective.

Unless specified otherwise, high tensile steel rivet conforming to IS:1149 shall be used for members of high tensile steel conforming to IS:961 and shall not be used for mild steel members.

Unless specified otherwise, bolted connection of structural joints using high tensile friction grip bolts shall comply with requirements of IS:4000.

Cast iron shall not be used in any portion of the bridge structure, except where it is subject to direct compression.

1903 MATERIALS

1903.1 All materials shall conform to Section 1000. Special requirements are given below :

Mild steel for bolts and nuts shall conform to IS:226 but have a minimum tensile strength of 44 kg/sq.mm and minimum percentage elongation of 14. High tensile steel for bolts and nuts shall conform to IS:961 but with a minimum tensile strength of 58 kg/sq.mm. High strength friction grip bolts shall be permitted for use only on satisfactory evidence of performance to the requirements (not covered by these specifications) specified by the Engineer or included in the special provisions.

For cast steel, the yield stress shall be determined and shall not be less than 50 percent of the minimum tensile strength.

Plain washers shall be of steel. Tapered or other specially shaped washers shall be of steel, or malleable cast iron.

Parallel barrel drifts shall have a tensile strength not less than 55 kg/sq.mm with elongation of not less than 20 per cent measured on a gauge length of 4 "So (So = cross-sectional area).

1903.2 Materials for castings and forgings, fasteners and welding consumables shall be as under :

1903.2.1 **Castings and Forgings :** Steel castings and forgings shall comply with the requirements of the following Indian Standards, as appropriate :

IS:1030	Carbon Steel Castings for General Engineering purposes
IS:1875	Carbon Steel Billets, blooms, slabs, bars for forgings
IS:2004	Carbon Steel Forgings for General Engineering purposes
IS:2644	High Tensile Steel Castings
IS:4367	Alloy and tool steel forgings for general industrial use

1903.2.2 **Fasteners :** Bolts, nuts washers and rivets shall comply with the following or relevant IS Standards as appropriate :

IS:1929	Hot forged steel rivets for hot closing (12-36 mm dia)
IS:2155	Cold forged steel rivets for hot closing (6-16 mm dia)
IS:1363	Hexagon head bolts, screw and nuts product grade C
IS:1364	Hexagon head bolts, screw & nuts product grade A and B
IS:1367 (Parts 1 to 18)	Technical supply conditions for threaded steel fastener
IS:3640	Hexagon fit bolts
IS:3757	High tensile friction grip bolts
IS:6623	High strength structural nuts
IS:6639	Hexagon bolts for steel structure
IS:5624	Foundation bolts
IS:7002	Prevailing torque type steel hexagon lock nuts

IS:5369	Plain washers and lock washers – general requirements
IS:5370	Plain washers with outside dia = 3 X inside dia
IS:5372	Taper washers for channels (ISMC)
IS:5374	Taper Washers for 1 beams (ISMB)
IS:6610	Heavy washers for steel structures
IS:6649	Hardened and tempered washers for high strength structural bolts and nuts.

1903.2.3 Welding consumables : Welding consumables shall comply with the following Indian Standards as appropriate :

IS:814 (Part 1)	Covered Electrodes for Metal Arc Welding of Structural steel for welding other than sheets
IS:814 (Part 2)	For welding sheets
IS:1278	Filler rods and wires for gas welding
IS:1395	Low and medium alloy Steel covered electrodes for manual Metal Arc Welding
IS:3613	Acceptance Tests for wire flux combinations for sub-merged arc welding of structural steel
IS:7280	Bare wire electrodes for gas shielded arc welding of structural steel
IS:6419	Welding rods and bare electrodes for gas shielded arc welding of structural steel
IS:6560	Molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding

1903.3 In aggressive environment, corrosion resistant steel can be used. These are low-alloyed steels containing a total of 1 percent – 2 percent alloys, in particular, copper, chromium, nickel and phosphorous.

1903.4 Paints

All materials for paints and enamels shall conform to the requirements specified on the drawings or other special provisions laid down by the Engineer.

The type of paints which can be used shall be as follows :

a) Ordinary i.e. paints based on drying oils, alkyd resin, modified alkyd resin, phenolic vamish epoxy

b) Chemical Resistant – one pack type (ready for use) ad two pack type (mixed before use).

c) Vinyl

d) Chlorinated rubber

e) Bituminous

f) Epoxy

g) Polyurethane

h) Zinc rich

Unless otherwise specified, paints shall conform to the relevant IS specifications. The paints which have been tested for the following qualities as per specifications given in the relevant IS codes only shall be used :

- Weight test (weight for 10 litre of paint, thoroughly mixed)
- Drying time
- Consistency
- Dry thickness and rate of consumption

1904 FABRICATION

1904.1 General

All work shall be in accordance with the drawings and as per these specifications with care being taken that all parts of an assembly fit accurately together. All members shall carry mark number and item number and, if required, serial number.

Unless specifically required under the contract, corresponding parts need not be interchangeable, but the parts shall be match marked as required under Clause 1904.7.

Templates, jigs and other appliances used for ensuring the accuracy of the work shall be of mild steel; where specially required, these shall be bushed with hard steel. All measurements shall be made by means of steel tape or other device properly calibrated. Where bridge materials have been used as templates for drilling, these shall be inspected and passed by the Engineer before they are used in the finished structure.

All structural steel members and parts shall have straight edges and blunt surfaces. If necessary, they shall be straightened or flattened by pressure unless they are required to be of curvilinear forms. They shall also be free from twist. Pressure applied for straightening or flattening shall be such as would not injure the materials. Hammering shall not be permitted. Adjacent surfaces or edges shall be in close contact or at uniform distance throughout.

The Contractor shall submit his programme of work to the Engineer for his approval at least 15 days before the commencement of fabrication. This programme shall include the proposed system of identification and erection marks together with complete details of fabrication and welding procedures.

The Contractor shall prepare shop drawings for fabricating any member and obtain approval of the Engineer before the start of work. Complete information regarding the location, type, size and extent of all welds shall be clearly shown on the shop drawings. These drawings shall distinguish between shop and field welds.

1904.2 Preparation of Edges and Ends

All structural steel-parts, where required, shall be sheared, cropped, sawn or flame cut and ground accurately to the required dimension and shape.

End/edge planning and cutting shall be done by any one of the following prescribed methods or left as rolled :

a) Shearing, cropping, sawing, machining, machine flame cutting.

b) Hand flame cutting with subsequent grinding to a smooth edge.

c) Sheared edges of plate not more that 16 mm thick with subsequent grinding to smooth profile, which are for secondary use such as stiffeners and gussets.

If ends of stiffeners are required to be fitted, they shall be ground, so that the maximum gap over 60 percent of the contact area does not exceed 0.25 mm.

Where flame cutting or shearing is used, at least one of the following requirements shall be satisfied.

a) The cut edge is not subjected to applied stress.

b) The edge is incorporated in weld.

c) The hardness of cut edge does not exceed 350 HV30.

d) The material is removed from edge to the extent of 2 mm or minimum necessary, so that the hardness is less than 350 HV 30.

e) Edge is suitably heat treated by approved method to the satisfaction of the Engineer and shown that cracks had not developed by dye penetrant or magnetic particle test.

f) Thickness of plate is less than 40 mm for machine flame cutting for materials conforming to IS:226 and IS:2062. The requirement of hardness below 350 HV 30 of flame cut edges should be specified by the Engineer.

Wherever specified by the Engineer, the flame cut edges shall be ground or machined over and above the requirement (a) to (f).

Where machining for edge preparation in butt joint is specified, the ends shall be machined after the members have been fabricated.

Outside edges of plate and section, which are prone to corrosion shall be smoothed by grinding or filing.

In the case of high tensile steel at least 6 mm of the material from the flame cut edge shall be removed by machining.

Longitudinal edges of all plates and cover plates in plate girders and built-up members shall be machined except in the following cases :

a) Rolled edges of single universal plates or flats may not be machined.

b) Covers to single flange plates may be left unmachined.

c) Machine flame cutting instead of machining is acceptable for edges of single plates in compression and for edges of single plates 25 mm or less thick, in tension.

d) Edges of single shaped plates over 2 mm thick not capable of being machined by ordinary method may be machine flame cut and the end surface ground.

e) Edges of universal plates or flats of the same nominal width used in tiers may be left unmachined, if so authorized by the Engineer.

All edges of splice and gusset plates 12 mm thick and over shall be machined and those less than 12 mm thick may be sheared and ground.

The ends of plates and sections forming the main components of plate girders or of built-up members shall be machined, machine flame cut, sawn or hand flame cut and ground.

Where ends of stiffeners are required to be fitted, they shall be machined, machine flame cut, sawn, sheared and ground, or hand flame cut and ground.

The ends of lacing bar shall be rounded unless otherwise required.

Other edges and ends of mild steel parts may be sheared and any burrs at edges shall be removed.

1904.3 Preparation of Holes

1904.3.1 Drilling and punching : Holes for rivets, black bolts, high strength bolts and countersunk bolts/rivets (excluding close tolerance and turn fitted bolts) shall be either punched or drilled. The diameter of holes shall be 1.5 mm larger for bolts/rivets less than 25 mm dia and 2.0 mm for more than or equal to 25 mm.

All holes shall be drilled except for secondary members such as, floor plate, hand rails etc. Members which do not carry the main load can be punched subject to the thickness of member not exceeding 12 mm for material conforming to IS:226.

Holes through more than one thickness of material or when any of the main material thickness exceeds 20 mm for steel conforming to IS:2062 or 16 mm for steel conforming to IS:961, IS:8500, shall either be sub-drilled or sub-punched to a diameter of 3 mm less than the required size and then reamed to the required size. The reaming of material more than one thickness shall be done after assembly.

Where several plates or sections form a compound member, they shall, where practicable, be firmly connected together by clamps or tacking bolts, and the holes be drilled through the group in one operation. Alternatively, and in the case of repletion work, the plates and sections may be drilled separately from jigs and templates. Jigs and templates shall be checked at least once after every 25 operations. All burrs shall be removed.

In the case of repetition of spans, the erection of every span shall not be insisted upon, except where close tolerance or turned bolts are used, provided that methods are adopted to ensure strict interchangeability. In such cases, one span in ten or any number less than ten of each type shall be erected from pieces selected at random by the Engineer and should there be any failure of the pieces to fit, all similar spans shall be erected complete. In the event of spans being proved completely interchangeable, all corresponding parts shall carry the same mark so that sorting of the materials at site is facilitated.

1904.3.2 Block drilling : Where the number of plates to be riveted exceeds three or the total thickness is 90 mm or more, the rivet holes, unless they have been drilled through steel bushed jigs, shall be drilled out in place 3 mm all round after assembling. In such cases, the work shall be thoroughly bolted together.

1904.3.3 Size of holes : The sizes of holes in mm are given in Table 1900-1.

Table 1900-1 Diameter of Holes for Rivets

Nominal dia of Rivets (mm)	Dia of Holes (mm)
12	13.5
14	15.5
16	17.5
18	19.5
20	21.5
22	23.5
24	25.5
27	29.0
30	32.0
33	35.0

1904.3.4 Close tolerance bolts and barrel bolts : Holes for closed tolerance and turn fitted bolts. The diameter of the holes shall be equal to the nominal diameter of the bolt shank minus 0.15 mm to 0.0 mm.

The members to be connected with closed tolerance or turn fitted bolts shall be firmly held together by service bolts or clamped and drilled through all thicknesses in one operation and subsequently reamed to required size within specified limit of accuracy as specified in IS:919 tolerance grade H8.

The holes not drilled through all thicknesses at one operation shall be drilled to smaller size and reamed after assembly.

1904.3.5 Holes for high strength friction grip bolts : All holes shall be drilled after removal of burrs. Where the number of plies in the grip does not exceed three, the diameters of holes shall be 1.6 mm larger than those of bolts and for more than three plies in grip, the diameters of hole in outer plies shall be as above and dia of holes in inner plies shall not be less than 1.6 mm and not more than 3.2 mm larger than those in bolts, unless otherwise specified by the Engineer.

1904.3.6 Removal of burrs : The work shall be taken apart after drilling and all burrs left by drilling and the sharp edges of all rivet holes completely removed.

1904.4 Rivet and Riveting

The diameter of rivets shown on the drawings shall be the size before heating. Each rivet shall be of sufficient length to form a head of the standard dimensions as given in IS handbook on Steel Sections, Part I. It shall be free from burrs on the underside of the head.

When countersunk heads are required, the heads shall fill the countersunk. The included angle of the head shall be as follows :

a) For plates over 14 mm thickness 90°

b) For plates upto and including 14 mm thickness 120°

The tolerance on the diameter of rivets shall be in accordance with IS:1148 and IS:1149 for mild steel rivets and high tensile steel rivets respectively and unless otherwise specified, the tolerance shall be minus tolerance.

Rivets shall be driven when hot so as to fill the hole as completely as possible and shall be of sufficient length to form a head of standard dimension. When counter-sunk head is required, the head shall fill the counter-sunk hole. Projection after counter-sinking shall be ground off wherever necessary.

Rivets shall be heated uniformly to a “light cherry red” colour between 650°C to 700°C for hydraulic riveting and “orange colour” for pneumatic riveting of mild steel rivets and shall be red hot from head to the point when inserted and shall be upset in its entire length so as to fill the hole as completely as possible when hot. Rivets, after being heated and before being inserted in the hole shall be made free from scale by striking the hot rivet on a hard surface.

Wherever possible, the rivets shall be machine driven, preferably by direct acting riveters. The driving pressure shall be maintained on the rivets for a short time after the upsetting is completed. High tensile steel rivets shall be heated upto 1100°C. Any rivet whose point is heated more than prescribed, shall not be driven.

Where flush surface is required, any projecting metal shall be chipped or ground off.

Before riveting is commenced, all work shall be properly bolted up so that the various sections and plates are in close contact throughout. Drifts shall only be used for drawing the work into position and shall not be used to such an extent as to distort the holes. Drifts of a larger size than the nominal diameter of the hole shall not be used. The riveting shall be done by hydraulic or pneumatic machine unless otherwise specified by the Engineer.

Driven rivets, when struck sharply on the head by a quarter pound rivet testing hammer, shall be free from movement and vibrations. Assembled riveted joint surfaces, including those adjacent to the rivet heads, shall be free from scale, dirt, loose scale, burrs, other foreign materials and defects that would prevent solid seating of parts.

All loose or burnt rivets and rivets with cracked or badly formed defective heads or heads which are unduly eccentric with the shanks, shall be removed and replaced. In removing rivets, the head shall be sheared off and the rivet punched out so as not to injure the adjacent

metal and, if necessary, they shall be drilled out. Recupping or recaulking shall not be permitted. The parts not completely riveted in the shop shall be secured by bolts to prevent damage during transport and handling.

1904.5 Bolts, Nuts and Washer

1904.5.1 Black bolts (black all over) : Black bolts are forged bolts in which the shanks, heads and nuts do not receive any further treatment except cutting of screw threads. They shall be true to shape and size and shall have the standard dimensions as shown on the drawings.

1904.5.2 Close tolerance bolts : Close tolerance bolts shall be faced under the head and turned on the shank

1904.5.3 Turned barrel bolts : The diameter of the screwed portion of turned barrel bolts shall be 1.5 mm smaller than the diameter of the barrel unless otherwise specified by the Engineer. The diameter of the bolts as given on the drawing shall be the nominal diameter of the barrel. The length of the barrel shall be such that it bears fully on all the parts connected. The threaded portion of each bolt shall project through the nut by at least one thread. Faces of heads and nuts bearing on steel work shall be machined.

1904.5.4 High strength friction bolts and bolted connections : The general requirement shall be as per relevant IS specifications mentioned in clause 5.3 of (Fasteners) of IRC:24. Unless otherwise specified by the Engineer, bolted connections of structural joints using high tensile frictions grip bolts shall comply with requirements mentioned in IS:4000.

1904.5.5 Washers : In all cases where the full bearing area of the bolt is to be developed, the bolt shall be provided with a steel washer under the nut of sufficient thickness to avoid any threaded portion of the bolt being within the thickness of the parts bolted together and to prevent the nut when screwed up, from bearing on the bolt.

For close tolerance or turned barrel bolts, steel washers whose faces given a true bearing shall be provided under the nut. The washer shall have a hole diameter not less than 1.5 mm larger than the barrel and thickness not less than 6 mm so that the nut when screwed up, will not bear on the shoulder of the bolt.

Taper washer with correct angle of taper shall be provided under all heads and nuts bearing on beveled surfaces.

Spring washers may be used under nuts to prevent slackening of the nuts when excessive vibrations occur.

Where the heads or nuts bear on timber, square washers having a length of each side not less than three times the diameter of bolts or round washers having a diameter of $3^{1/2}$ times the diameter of bolts and with a thickness not less than one quarter of diameter shall be provided.

1904.5.6 Studs : Ordinary studs may be used for holding parts together, the holes in one of the parts being tapped to take the thread of the stud. Counter-sunk studs may be used for making connections where the surfaces are required to be clear of all obstruction, such as protruding heads of bolts or rivets, studs may also be welded on the steel work in the positions required.

1904.5.7 Service bolts : Service bolts shall have the same clearance as black bolts and where it is required that there should be no movement prior to final riveting, sufficient drifts or close tolerance bolts shall be used to locate the work.

1904.5.8 Tightening bolts : Bolted connection joints with black bolts and high strength bolts shall be inspected for compliance of codal requirements.

The Engineer shall observe the installation and tightening of bolts to ensure that correct tightening procedure is used and shall determine that all bolts are tightened. Regardless of tightening method used, tightening of bolts in a joint should commence at the most rigidly fixed or stiffest point and progress towards the free edges, both in initial snugging and in final tightening.

The tightness of bolts in connection shall be checked by inspection wrench, which can be torque wrench, power wrench or calibrated wrench.

Tightness of 10 percent bolts, but not less than two bolts, selected at random in each connection shall be checked by applying inspection torque. If no nut or bolt head is turned by this application, connection can be accepted as properly tightened, but if any nut or head has turned, all bolts shall be checked and, if necessary, re-tightened.

1904.5.9 Drifts : The barrel shall be drawn or machined to the required diameter for a length of not less than one diameter over the combined thickness of the metal through which the drifts have to pass. The diameter of the parallel barrel shall be equal to the nominal diameter of the hole subject to a tolerance of +0 mm and 0.125 mm. Both ends of the drift for a length equal to $1^{1/2}$ times the diameter of the parallel portion of the bar shall be turned down with a taper to a diameter at the end equal to one-half that of parallel portion.

1904.6 Pins and Pin Holes

1904.6.1 Pins : The pins shall be parallel throughout and shall have a smooth surface free from flaws. They shall be of sufficient length to ensure that all parts connected thereby

shall have a full bearing on them. Where the ends are threaded, they shall be turned to a smaller diameter at the ends for the thread and shall be provided with a pilot nut, where necessary, to protect the thread when being drawn to place.

Pins more than 175 mm in length or diameter shall be forged and annealed.

1904.6.2 Pins holes : Pin holes shall be bored true to gauge, smooth, straight at right angles to the axis of the member and parallel with each other, unless otherwise required. The tolerance in the length of tension members from outside to outside of pin holes and of compression members from inside to inside of pin holes shall be one millimeter. In built-up members, the boring shall be done after the members have been riveted or welded.

The specified diameter of the pin hole shall be its minimum diameter. The resulting clearance between the pin and the hole shall not be less than 0.5 mm and not more than 1.0 mm.

1904.7 Shop Erection and Match Marking

Before being dispatched, the steel work shall be temporarily erected in the fabrication shop for inspection by the Engineer either wholly or in such portion as the Engineer may require so that he may be satisfied both in respect of the alignment and fit of all connections. For this purpose, sufficient number of parallel drifts and service bolts tightly screwed up shall be employed. All parts shall fit accurately and be in accordance with drawings and specifications.

The steel work shall be temporarily assembled at place of fabrication. Assembly shall be of full truss or girder, unless progressive truss or girder assembly, full chord assembly, progressive chord assembly or special complete structure assembly is specified by the Engineer.

The field connections of main members of trusses, arches, continuous beams, spans, bends, plate girders and rigid frame assembled, aligned, accuracy of holes and camber shall be checked by the Engineer and then only reaming of sub-size holes to specified size shall be taken up.

After the work has been passed by the Engineer and before it is dismantled, each part shall be carefully marked for re-erection with distinguishing marks and stamped with durable markings. Drawings showing these markings correctly shall be supplied to the Engineer.

Unloading, handling and storage of steel work as per these specifications shall be the responsibility of the Contractor. The cost of repairs or of rejected material, its removal and the cost of transporting replacement material to the site shall be borne by the Contractor.

Where close tolerance or turned barrel bolts are used for those cases where interchangeability is not insisted upon, each span shall be erected and members of each span marked distinctly.

1904.8 Welding

1904.8.1 All welding shall be done with the prior approval of the Engineer and the workmanship shall conform to the specifications of IS:823 or other relevant Indian Standards as appropriate.

When material thickness is 20 mm or more, special precautions like preheating shall be taken as laid down in IS:823. Surfaces and edges to be welded shall be smooth, uniform and free from fins, tears, cracks and other discontinuities. Surface shall also be free from loose or thick scale, slag rust, moisture, oil and other foreign materials. Surfaces within 50 mm of any weld location shall be free from any paint or other material that may prevent proper welding or cause objectionable fumes during welding.

The general welding procedures including particulars of the preparation of fusion faces for metal are welding shall be carried out in accordance with IS:9595.

The welding procedures for shop and site welds including edge preparation of fusion faces shall be submitted in writing in accordance with Clause 22 of IS:9595 for the approval of the Engineer before commencing fabrication and shall also be as per details shown on the drawings. Any deviation from above has to be approved by the Engineer. Preparation of edges shall, wherever practicable, be done by machine methods.

Machine flame cut edges shall be substantially as smooth and regular as those produced by edge planning and shall be left free of slag. Manual flame cutting shall be permitted by the Engineer only where machine cutting is not practicable.

Electrodes to be used for metal arc welding shall comply with relevant IS Specifications mentioned in IRC:24. Procedure test shall be carried out as per IS:8613 to find out suitable wire-flux combination for welded joint.

Assembly of parts for welding shall be in accordance with provisions of IS:9595.

The welded temporary attachment should be avoided as far as possible, otherwise the method of making any temporary attachment shall be approved by the Engineer. Any scars from temporary attachment shall be removed by cutting, chipping and surface shall be finished smooth by grinding to the satisfaction of the Engineer.

Welding shall not be done when the air temperature is less than 10°C. Welding shall not be done when the surfaces are moist, during periods of strong winds or in snowy weather unless the work and the welding operators are adequately protected.

1904.8.2 For welding of any particular type of joint, welders shall qualify to the satisfaction of the Engineer in accordance with appropriate welders qualification test as prescribed in any of the Indian Standards IS:817, IS:1966, IS:1393, IS:7307 (Part I), IS:7310 (Part I) and IS:7318 (Part I) as relevant.

1904.8.3 In assembling and joining parts of a structure or of built-up members, the procedure and sequence of welding shall be such as to avoid distortion and minimise shrinkage stress.

All requirements regarding pre-heating of parent material and interpass temperature shall be in accordance with provision of IS:9595.

1904.8.4 Peening of weld shall be carried out wherever specified by the Engineer :

a) If specified, peening may be employed to be effective on each weld layer except first.

b) The peening should be carried out after weld has cooled by light blows from a power hammer using a round note tool. Care shall be taken to prevent scaling or flaking of weld and base metal from over peening.

1904.8.5 Where the Engineer has specified the butt welds are to be ground flush, the loss of parent metal shall not be greater than that allowed for minor surface defects. The ends of butt joints shall be welded so as to provide full throat thickness. This may be done by use of extension pieces, cross runs or other means approved by the Engineer. Extension pieces shall be removed after the joint has cooled and the ends of the weld shall be finished smooth and flush with the faces of the abutting parts.

The joints and welds listed below are prohibited type, which do not perform well under cyclic loading.

a) Butt joints not fully welded throughout their cross-section

b) Groove welds made from one side only without any backing grip

c) Intermittent groove welds

d) Intermittent filled welds

e) Bevel-grooves and J-grooves in butt joints for other than horizontal position

f) Plug and slot welds

1904.8.6 The run-on and run-off plate extension shall be used providing full throat thickness at the end of butt welded joints. These plates shall comply with the following requirements.

i) One pair of "run-on" and one pair of "run-off" plates prepared from same thickness and profile as the parent metal shall be attached to start and finish of all butt welds preferably by clamps.

ii) When "run-on" and "run-off" plates shall be removed by flame cutting, it should be cut at more than 3 mm from parent metal and remaining metal shall be removed by grinding or by any other method approved by the Engineer.

1904.8.7 Welding of stud shear connectors : The stud shear connectors shall be welded in accordance with the manufacturer's instructions including preheating.

The stud and the surface to which studs are welded shall be free from scale, moisture, rust and other foreign material. The stud base shall not be painted, galvanised or cadmium plated prior to welding.

Welding shall not be carried out when temperature is below 10°C or surface is wet or during periods of strong winds unless the work and the welder is adequately protected.

The welds shall be visually free from cracks and shall be capable of developing at least the nominal ultimate strength of studs.

The procedural trial for welding the stud shall be carried out when specified by the Engineer.

1904.9 Tolerances

Tolerances in dimensions of components of fabricated structural steel work shall be specified on the drawings and shall be subject to the approval of the Engineer before fabrication. Unless specified, all parts of an assembly shall fit together accurately within tolerances specified in Table 1900-2.

A machined bearing surface, where specified by the Engineer, shall be machined within a deviation of 0.25 mm for surfaces that can be inscribed within a square of side 0.5 m.

1905 ERECTION

1905.1 General

The provisions of this item shall apply to erection of steel bridge superstructures or main members of bridge superstructures, composed of steel, which span between supports.

Table 1900-2 Fabrication Tolerances

A.	**INDIVIDUAL COMPONENTS**				
	1.	Length			
		a)	Member with both ends finished for Contact bearing		± 1 mm
		b)	Individual components of members with end plate connection		+ 0 mm - 2 mm
		c)	Other members		
			i)	Upto and including 12 M	± 2 mm
			ii)	Over 12 M	± 3.5 mm
	2.	Width			
		a)	Width of built-up girders		± 3 mm
		b)	Deviation in the width of members required to be inserted in other members		+ 0 mm - 3 mm
	3.	Depth Deviation in the depths of solid web and open web girders			+ 3 mm - 2 mm
	4.	Straightness			
		a)	Deviation from straightness of a columns		L/3000 subject to maximum of 15 mm where L is length of member
			i)	In elevation	+ 5 mm - 0 mm
			ii)	In plan	L/1000 subject to a maximum of 10 mm
	5.	Deviation of center line of web from centre line of flanges in built-up members at contact surface			3 mm
	6.	Deviation from flatness of plate of webs of built-up members in a length equal to the depth of the members			0.005 d to a maximum of 2 mm where d is depth of the member

7.	Tilt of flange of plate girders		
	a)	At splices and stiffeners, at supports, at the top flanges of plate girders and at bearings	0.005 b to a minimum of 2 mm where b is width of the member
	b)	at other places	0.015 b to a maximum of 4 mm where b is width of the member
8.	Deviation from squareness of flange to web of columns and box girders of the diagonal		L/1000, where L is nominal length
9.	Deviation from squareness of fixed base plate (not machined) to axis of columns. This dimension shall be measured parallel to the longitudinal axis of the column at points where the outer surfaces of the column sections make contact with the base plate		D/500, where D is the distance from the column axis to the point under consideration on the base plate
10.	Deviation from squareness of machined ends to axes of columns		D/1000, where D is as defined in 9 above
11.	Deviation from squareness of machined ends to axes of beams machined ends to axes of beams		D/1000, where D is as defined in 9 above
12.	Ends of members abutting at joints through cleats or end plates, permissible deviation from squareness of ends		1/600 of depth of member subject to a maximum of 1.5 mm

If the sub-structure and the superstructure are built under separate contracts, the Employer will provide the substructure, constructed to correct lines, dimensions and elevations properly finished and will establish the lines and the elevation required for setting steel.

The Contractor shall erect the structural steel, remove the temporary construction, and do all the work required to complete the construction included in the contract in accordance with the drawings and the specifications and to the entire satisfaction of the Engineer.

1905.2 Organisation and Equipment

The Contractor shall submit erection plans prepared by the fabricator showing a method and procedure of erection, compatible with the details of fabrication.

A detailed scheme must be prepared showing stage-wise activities, with complete drawings and working phase-wise instructions. This should be based on detailed stage-wise calculation and taken into account specifications and capacity of erection equipment machinery, tools, tackles to be used and temporary working loads as per codal provisions.

The scheme should be based on site conditions e.g. hydrology, rainfall, flood timings and intensity, soil and sub-soil conditions in the river bed and banks, maximum water depth, temperature and climatic conditions and available working space, etc.

The scheme should indicate precisely the type of temporary fasteners to be used as also the minimum percentage of permanent fasterners to be fitted during the stage erection. The working drawings should give clearly the temporary jigs, fixtures, clamps, spacer supports, etc.

Unless otherwise provided in the contract, the Contractor shall supply and erect all necessary falsework and staging and shall supply all labour, tools, erection plant and other materials necessary to carry out the work complete in all respects.

The Contractor shall supply all rivets, bolts, nuts, washers, etc. required to complete erection at site with an allowance for wastage etc., of 12½ percent of the net number of field rivets, bolts, washers required, or a minimum of five number of each item.

Service bolts and nuts, ordinary platters, washers and drifts for use in erection of work shall be supplied at 60 percent (45 percent bolts and 15 percent drifts) of the number of field rivets per span in each size (this includes wastage). A reduction in the quantities of service bolts, etc., may however, be specified by the Engineer if more than one span of each type is ordered.

Prior to actual commencement of erection, all equipment, machinery, tools, tackles, ropes, etc. need to be tested to ensure their efficient working. Frequent visual inspection is essential in vulnerable areas to detect displacements, distress, drainages, etc.

Deflection and vibratory tests shall be conducted in respect of supporting structures, launching truss as also the structure under erection and unusual observations reviewed; looseness of fittings are to be noted.

For welded structures, welders' qualifications and skill are to be checked as per standard norms. Non-destructive tests of joints as per designer's directives are to be carried out.

Precision non-destructive testing instruments available in the market should be used for noting various important parameters of the structures frequently and systematic record is to be kept.

Safety requirements should conform to IS:7205, IS:7273 and IS:7269 as applicable and should be a consideration of safety, economy and rapidity.

Erection work should start with complete resources mobilized as per latest approved drawings and after a thorough survey of foundations and other related structural work. In case of work of magnitude, maximum mechanization is to be adopted.

The structure should be divided into erectable modules as per the scheme. This should be pre-assembled in a suitable yard/platform and its matching with members of the adjacent module checked by trial assembly before erection.

The structure shall be set out to the required lines and levels. The stocks and masses are to be carefully preserved. The steelwork should be erected, adjusted and completed in the required position to the specified lines and levels with sufficient drifts and bolts. Packing materials are to be available to maintain this condition. Organised "Quality Surveillance" checks need to be exercised frequently.

Before starting work, the Contractor shall obtain necessary approval of the Engineer as to the method adopted for erection, the number and character of tools and plants. The approved of the Engineer shall not relieve the Contractor of his responsibility for the safety of his method or equipment or from carrying out the work fully in accordance with the drawings and specifications.

During the progress of work, the Contractor shall have a competent engineer or foreman in charge of the work, who shall be adequately experienced in steel erection and acceptable to the Engineer.

1905.3 Handling and Storing of Materials

Suitable area for storage of structures and components shall be located near the site of work. The access road should be free from water logging during the working period and the storage area should be leveled and firm ground.

The store should be provided with adequate handling equipments e.g. road mobile crane, gantries, derricks, chain pulley blocks, winch of capacity as required. Stacking area should be planned and have racks, stands sleepers, access tracks, etc., and properly lighted.

Storage should be planned to suit erection work sequence and avoid damage or distortion. Excessively rusted, bent or damaged steel shall be rejected. Methods of storage and handling steel, whether fabricated or not shall be subject to the approval of the Engineer.

Fabricated materials are to be stored with erection marks visible, such as not to come into contact with earth surface or water and should be accessible to handling equipment.

Small fitting hand tools are to be kept in containers in covered stores.

All materials, consumables, including raw steel or fabricated material shall be stored specification-wise and size-wise above the ground upon platforms, skids or other supports. It shall be kept free from dirt and other foreign matter and shall be protected as far as possible from corrosion and distortion. The electrodes shall be stored specification-wise and shall be kept in dry warm condition in properly designed racks. The bolts, nuts, washers and other fasteners shall be stored on racks above the ground with protective oil coating in gunny bags. The paint shall be stored under cover in air-tight containers.

IS:7293 and IS:7969 dealing with handling of materials and equipments for safe working should be followed. Safety nuts and bolts as directed are to be used while working. The Contractor shall be held responsible for loss or damage to any material paid for by the Employer while in his care or for any damage to such material resulting from his work.

1905.4 Formwork

The formwork shall be properly designed, substantially built and maintained for all anticipated loads. The Contractor, if required, shall submit plans for approval to the Engineer. Approval of the plans, however, shall not relieve the Contractor of his responsibility.

1905.5 Straightening Bent Material

The straightening of plates, angles and other shapes shall be done by methods not likely to produce fracture or any injury. The metal shall not be heated unless permitted by the Engineer for special cases, when the heating shall not be to a temperature higher than that producing a dark cherry red colour, followed by as slow cooling as possible. Following the straightening of a bend or buckle, the surface shall be carefully investigated for evidence of fracture. Sharp kinks and bends may be the cause for rejection of material.

1905.6 Assembling Steel

The parts shall be accurately assembled as shown on the drawings and match marks shall be followed. The material shall be carefully handled so that no parts will be bent, broken or otherwise damaged.

Hammering which will injure or distort the members shall not be done. Bearing surface or surfaces to be in permanent contact shall be cleaned, before the members are assembled. The truss spans shall be erected on blocking, so placed as to give the proper camber. The blocking shall be left in place until the tendon chord splices are fully riveted and all other truss connections pinned and bolted. Rivets in splices of butt joints of compression members and rivets in railings shall not be driven until the span has been swung.

All joint surface for bolted connections including bolts, nuts, washers shall be free from scale, dirt, burrs, other foreign materials and defects that would prevent solid seating of parts. The slope of surface of bolted parts in contact with bolt head and nut shall not exceed 1 in 20, plane normal to bolt axis, otherwise suitable tapered washer shall be used.

All fasteners shall have a washer under nut or bolt head whichever is turned in tightening.

Any connection to be riveted or bolted shall be secured in close contact with service bolts or with a sufficient number of permanent bolts before the rivets are driven or before the connections are finally bolted. Joints shall normally be made by filling not less than 50 percent of holes with service bolts and barrel drifts in the ratio 4:1. The service bolts are to be fully tightened up as soon as the joint is assembled. Connections to be made by close tolerance or barrel bolts shall be completed as soon as practicable after assembly.

Any connection to be site welded shall be securely held in position by approved methods to ensure accurate alignment, camber and elevation before welding is commenced.

The field riveting, welding, bolted and pin connection shall conform to the requirements of Clause 1904 as appropriate.

The correction of minor misfits involving harmless amounts of reaming, cutting and chipping will be considered a legitimate part of erection. However, any error in the shop fabrication or deformation resulting from handling and transportation which prevents proper assembling and fitting up of parts by moderate use of drifts or by a moderate amount of reaming and slight chipping or cutting shall be reported immediately to the Engineer and his approval of the method of correction obtained. The correction shall be made in the presence of the Engineer.

1905.7 Field Inspection

1905.7.1 General

All materials equipment and work of erection shall be subject to the inspection of the Engineer who shall be provided with all facilities including labour and tools required at all reasonable times. Any work found defective is liable to be rejected.

1905.7.2 No protective treatment shall be applied to the work until the appropriate inspection and testing has been carried out. The stage inspection shall be carried out for all operations so as to ensure the correctness of fabrication and good quality. Girder dimensions and camber shall not be finally checked until all welding and heating operations are completed and the member has cooled to a uniforms temperature.

1905.7.3 Testing of material : Structural steel shall be tested for mechanical and chemical properties as per various IS codes as may be applicable and shall conform to requirements specified in IS:226, IS:2062, IS:11587, IS:1977, IS:8500 and IS:961, etc.

Rivets, bolts, nuts, washers, welding consumables, steel forging, casting and stainless steel shall be tested for mechanical and chemical properties in the appropriate IS Code.

Rolling and cutting tolerance shall be as per IS:1852. The thickness tolerance check measurements for the place and rolled sections shall be taken at not less than 15 mm from edge.

Laminations in plates shall be carried out by ultra-sonic testing or any other specified methods.

Steel work shall be inspected for surface defects and exposed edge laminations during fabrication and blast cleaning. Significant edge laminations found shall be reported to the Engineer for his decision.

Chipping, grinding, machining or ultrasonic testing shall be used to determine depth of imperfection.

1905.7.4 Bolted connections : Bolts and bolted connection joints with high strength friction grip bolts shall be inspected and tested according to IS:4000.

Rivets and riveted connection shall be inspected and tested for compliance of codal requirements.

The firmness of joint shall be checked by 0.2 mm filler gauge, which shall not go inside under the rivet head by more than 3 mm. There shall not be any gap between members to be riveted.

Driven rivets shall be checked with rivet testing hammer. When struck sharply on head with rivet testing hammer, rivet shall be free from movement and vibration.

All loose rivets and rivets with cracks, badly formed or deficient heads or with heads which are eccentric with shanks, shall be cut out and replaced.

The alignment of plates at all bolted splice joints and welded butt joints shall be checked for compliance with codal requirements.

Testing of flame cut and sheared edges is to be done, where the hardness criteria given in the code are adopted. Hardness testing shall be carried out on six specimens

1905.7.5 Welding and welding consumables : Welding procedure, welded connection and testing shall be in compliance with codal requirements.

All facilities necessary for stage inspection during welding and on completion shall be provided to the Engineer or their inspecting Authority by manufacturer.

Adequate means of identification either by identification mark or other record shall be proved to enable each weld to be traced to the welder(s) by whom it was carried out.

All metal arc welding shall be in compliance with IS:9595 provisions.

The method of inspection shall be in accordance with IS:822 and extent of inspection and testing shall be in accordance with the relevant standards or in the absence of such a standard, as agreed with the Engineer.

Procedure tests

The Destructive and Non-Destructive test of weld shall be carried out according to IS:7307 (Part I).

Non-Destructive Testing of Welds

One or more of the following methods may be applied for inspection or testing of weld :

i) **Visual Inspection** : All welds shall be visually inspected, which should cover all defects of weld such as size, porosity, crack in the weld or in the HAZ (Heat Affected Zone) etc. Suitable magnifying glass may be used for visual inspection. A weld shall be acceptable by visual inspection if it shows that :

   a) The weld has no cracks.

   b) Through fusion exists between weld and base metal and between adjacent layers of weld metal.

   c) Weld profiles are in accordance with requisite clauses of IS:9595 or as agreed with the Engineer.

d) The weld shall be of full cross section, except for the ends of intermittent fillet welds outside their effective length.

e) When weld is transverse to the primary stress, undercut shall not be more than 0.25 mm deep in the part that is undercut and shall not be more than 0.8 mm deep when the weld is parallel to the primary stress in the part that is under cut.

f) The fillet weld in any single continuous weld shall be permittedto under run the nominal fillet weld size specified by 1.6 mm without correction provided that undersize portion of the weld does not exceed 10 per cent of the length of the weld. On the web-to-flange welds on girders, no under-run is permitted at the ends for a length equal to twice the width of the flange.

g) The piping porosity in fillet welds shall not exceed one in each 100 mm of weld length and the maximum diameter shall not exceed 2.4 mm, except for fillet welds connection stiffeners to web where the sum of diameters of piping porosity shall not exceed 9.5 mm in any 25 mm length of weld and shall not exceed 19 mm in any 300 mm length of weld.

h) The full penetration groove weld in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the piping porosity shall not exceed one in 100 mm of length and the maximum diameter shall not exceed 2.4 mm.

ii) **Magnetic Particle and Radiographic Inspection :** Welds that are subject to radiographic or magnetic particle testing in addition to visual inspection shall have no crack.

Magnetic particle test shall be carried out for detection of crack and other discontinuity in the weld according to IS:5334.

Radiographic test shall be carried out for detection of internal flaws in the weld such as crack, piping porosity inclusion, lack of fusion, incomplete penetration, etc. This test may be carried out as per IS:1182 and IS:4853.

iii) **Ultrasonic Inspection :** The Ultrasonic testing in addition to visual inspection shall be carried out for detection of internal flaws in the weld such as cracks, piping porosity inclusion, lack of fusion, incomplete penetration, etc. Acceptance criteria shall be as per

IS:4260 or any other relevant IS Specification and as agreed to by the Engineer.

iv) **Liquid Penetration Inspection :** The liquid penetrant test shall be carried out for detection of surface defect in the weld, as per IS:3658, in addition to visual inspection

The non-destructive testing of following welds be carried out using one of the method or methods described at (ii), (iii) and (iv) above, as may be agreed to by the Engineer.

a) All transverse butt welds in tension flange
b) 10 percent of the length of longitudinal and transverse butt welds in tension flanges.
c) 5 percent of the length of longitudinal and transverse butt welds in compression flanges.
d) All transverse butt welds in webs adjacent to tension flanges as specified by the Engineer.

The particular length of welds in webs to be tested shall be agreed with the Engineer, in case (b) or (c).

Where specified by the Engineer, bearing stiffeners or bearing diaphragms adjacent to welds, flange plates adjacent to web/flange welds, plates at cruciform welds, plates in box girder construction adjacent to corner welds or other details shall be ultrasonically tested after fabrication.

Any lamination, lamellar tearing or other defect found shall be recorded and reported to the Engineer for his decision.

Testing of Welding for Cast Steel : The testing of weld for cast steel shall be carried out as may be agreed to by the Engineer.

Stud Shear Connectors : Stud shear connectors shall be subjected to the following tests :

a) The fixing of studs after being welded in position shall be tested by striking the side of the head of the stud with a 2 kg hammer to the satisfaction of the Engineer.

b) The selected stud head stroked with 6 kg hammer shall be capable of lateral displacement of approximately 0.25 the height of the stud from its original position. The stud weld shall not show any sign of crack or lack of fusion.

The studs whose welds have failed the tests given in (a) and (b) shall be replaced.

1905.7.6 Inspection requirement : The fabricated member/component made out of rolled and built-up section shall be checked for compliance of the tolerances given in Table 1900-2. Inspection of member/components for compliance with tolerances, and the check for deviations shall be made over the full length.

During checking, the inspection requirement shall be placed in such a manner that local surface irregularities do not influence the results.

For plate, out-of-plane deviation shall be checked at right angle to the surface over the full area of plate.

The relative cross-girder or cross frame deviation shall be checked over the middle third of length of the cross girder or frame between each pair of webs and for cantilever at the end of member.

The web of rolled beam or channel section shall be checked for out-of-plane deviation in longitudinal direction equal to the depth of the section.

During inspection, the component/member shall not have any load or external restraint.

Inspection Stages : The inspection to be carried out for compliance of tolerances shall include but not be limited to the following stages :

a) For completed parts, component/members on completion of fabrication and before any subsequent operation such as surface preparation, painting, transportation, erection.

b) For webs of plate and box girder, longitudinal compression flange stiffeners in box girders and orthotropic decks and all web stiffeners at site joints, on completion of site joint.

c) For cross girders and frames, cantilevers in orthotropic decks and other parts in which deviations have apparently increased on completion of site assembly.

Where, on checking member/component for the deviation in respect of out-of-plane or out-of-straightness at right angles to the plate surface, and any other instances, exceed tolerance, the maximum deviation shall be measured and recorded. The recorded measurements shall be submitted to the Engineer who will determine whether the component/member may be accepted without rectification, with rectification or rejected.

1906 PAINTING

1906.1 General

Unless otherwise specified, all metal work shall be given approved shop coats as well as field coats of painting. The item of work shall include preparation of metal surfaces, application of protective covering and drying of the paint coatings and supply of all tools, scaffolding, labour and materials necessary.

Coatings shall be applied only to dry surfaces and the coated surfaces shall not be exposed to rain or frost before they are dry. The coatings shall be applied to all surfaces excluding shear connectors and inner surfaces of fully sealed hollow sections. Care shall be taken during coating of adjacent surfaces to build up primer on the shear connectors.

1906.1.1 Types of paints

i) Ordinary Paints

These include paints based on drying oils, alkyd resin, modified alkyd resin, phenolic varnish epoxy, etc.

Alkyd resin paints for the protection of steel structures are based partly on natural oils and partly on synthetic resins. These paints shall be used for steel structures in atmospheres which are not too aggressive.

Oil based paints can be used for steel structures in cases where the surface preparation cannot be ideal. Ordinary painting can generally be sub-divided into two groups:

a) Primary Coats :

This shall be applied immediately after the surface preparation and should have the properties of adhesion, corrosion inhibition and imperviousness to water and air.

b) Finishing Coats :

This shall be applied over the primary coat and should have the properties of durability, abrasion resistance, aesthetic appearance and smooth finish.

ii) Chemical Resistant Paints

The more highly corrosion resistant paints can be divided into two main groups :

a) One pack paints (ready for use)

b) Two pack paints (mixed before use)

The two pack paints shall be mixed together immediately before use since they are workable thereafter only for a restricted period of time and dry up as a result of a reaction between their components and yield hard tough films with resistance to abrasion.

iii) Vinyl Paints

These are based on polyvinyl resins such as polyvinyl-chloride (PVC) and polyvinyl-acetate, etc.

Certain types of vinyl resin paints yield thick, relatively soft and rubber like coatings with good chemical resistance. They can be repainted without difficulty.

iv) Chlorinated Rubber Paints

These paints also have good chemical resistance. The main fields of applications shall be in aggressive environments. In general, chlorinated rubber paints do not have a high gloss.

v) Bituminous Paints

As a paint vehicle, bituminous is inferior, but because of the low price, this should be applied in greater thickness (upto several millimeters) and may be suitable for some situations. A significant advantage of bitumen paints is their impermeability to ingress of water. However, bituminous paints do not withstand effectively detrimental effects of oil.

(vi) Bituminous Paints

These resin paints have good adherence to a well prepared sub-strata. They are mechanically strong and resistant to chemicals. A disadvantage of epoxy resin paints is that it can rapidly become dull when exposed to strong sunlight. These disadvantages do not, however, greatly influence their protective power.

(vii) Polyurethane paints

The chemical and mechanical behaviour of polyurethane paint resembles those of epoxy paint very much. However, polyurethane paint retains its gloss for a longer period. Because of the high price of polyurethane paint, a combination of the two viz., polyurethane and epoxy paints may sometimes be used.

(viii) Zinc Rich Paints

Instead of introducing an inhibitive pigment into paint, metallic zinc can be used and such paints can provide cathodic protection to steel.

1906.1.2 Surfaces which are inaccessible for cleaning and painting after fabrication shall be painted as specified before being assembled for riveting.

All rivets, bolts, nuts, washer etc., are to be thoroughly cleaned and dipped into boiling linseed oil conforming to IS:77.

All machined surfaces are to be well coated with a mixture of white lead conforming to IS:34 and Mutton Tallow conforming to IS:887.

For site paintings, the whole of the steel work shall be given the second cover coat after final passing and after touching up the primer and cover coats, if damaged in transit.

1906.1.3 Choice of painting system

The choice of suitable painting system is dependent on factors such as :

- Available application methods viz. brush, roller or spray
- Durability in a specific environment
- Availability of skilled manpower
- Cost effectiveness

It is therefore necessary to consult various manufacturers of paint and ascertain the above aspects while deciding on the appropriate choice of painting system.

1906.1.4 Quality of paint : The paints which have been tested for the following qualities as per the specifications given in the relevant IS codes should only be used :

- Weight Test (weight per 10 litre of paint thoroughly mixed)
- Drying time
- Flexibility and Adhesion
- Consistency
- Dry thickness and rate of consumption

1906.1.5 Unless otherwise specified, all painting and protective coating work shall be done in accordance with IS:1477 (Part I).

1906.2 Surface Preparation

Steel surface to be painted either at the fabricating shop or at the site of work shall be prepared in a thorough manner with a view to ensuring complete removal of mill scale by one of the following processes as agreed to between the fabricator and the Engineer :

a) Dry of wet grit/Sand blasting

b) Pickling which should be restricted to single plates, bars and sections

c) Flame cleaning

Primary coat shall be applied as soon as practicable after cleaning and in case of flame cleaning, primary coat shall be applied while the metal is still warm.

All slag from welds shall be removed before painting. Surfaces shall be maintained dry and free from dirt and oil. Work out of doors in frosty or humid weather shall be avoided.

1906.3 Coatings

Prime coat to be used shall conform to the specification of primers approved by the Engineer. Metal coatings shall be regarded as priming coatings. Primer shall be applied to the blast cleaned surface before any deterioration of the surface is visible. In any case, the surface shall receive one coat of primer within 4 hours of abrasive blast cleaning.

All coats shall be compatible with each other. When metal coatings are used, the undercoat shall be compatible with the metal concerned. The undercoat and finishing coat shall preferably be from the same manufacturer. Successive coats of paints shall be of different shades or colours and each shall be allowed to dry thoroughly before the next is applied. Particular care shall be taken with the priming and painting of edges, corners, welds and rivets. Typical guidelines for epoxy based paints and the conventional painting system for bridge girders as given below may be complied with :

a) **Epoxy Based Painting**

i) Surface preparation : Remove oil/grease by use of petroleum hydrocarbon solution (IS:1745) and Grit blasting to near white metal surface.

ii) Paint system : 2 coats of epoxy zinc phosphate primer = 60 micron : Total 5 coats = 200 micron

b) **Conventional Painting System for areas where corrosion is not severe**

Priming Coat :

One heavy coat or ready mixed paint, red lead primer conforming to IS:102

or

One coat of ready mixed zinc chrome primer conforming to IS:104 followed by one coat of ready mixed red oxide zinc chrome primer conforming to IS:2074.

or

Two coats of zinc chromate red oxide primer conforming to IS:2074.

Finishing Coats :

Two cover coats of red oxide paint conforming to IS:123 or any other approved paint shall be applied over the primer coat. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second coat shall be given after touching up the primer and the cover coats if damaged in transit.

c) Conventional Painting System for areas where corrosion is severe

Priming Coat :

Two coats or ready mixed red lead primer conforming to IS:102

or

One coat of ready mixed zinc chrome primer conforming to IS:104 followed by one coat of ready zinc chromate conforming to IS:2074.

Finishing Coats :

Two coats of aluminium paint conforming to IS:2339 shall be applied over the primer coat. One coat shall be applied before the fabricated steel work leaves the shop. After the steel work is erected at site, the second coat shall be given after touching up the primer and the cover coats if damaged in transit.

1906.4 Painting in the Shop

All fabricated steel shall be painted in the shops after inspection and acceptance with at least one priming coat, unless the exposed surfaces are subsequently to be cleaned at site or are metal coated. No primer shall be applied to galvanised surfaces.

Shop contact surfaces, if specifically required to be painted, shall be brought together while the paint is still wet.

Field contact surfaces and surfaces to be in contact with cement shall be painted with primer only. No paint shall be applied within 50mm of designed location of filed welds. Paint shall be completely dried before loading and transporting to site.

Surface not in contact but inaccessible after shop assembly shall receive the fully specified protective treatment before assembly.

Where surfaces are to be welded, the steel shall not be painted or metal coated within a suitable distance from any edges to be welded if the specified paint or metal coating would be harmful to welders or is expected to impair the quality of site welds.

Exposed machined surfaces shall be adequately protected.

1906.5 Painting at Site

Surfaces which will be inaccessible after site assembly shall receive the full specified protective treatment before assembly.

Surfaces which will be in contact after site assembly shall receive a coat of paint (in addition to any shop priming) and shall be brought together while the paint is still wet.

Damaged or deteriorated paint surfaces shall be first made good with the same type of coat as the shop coat.

Where steel has received a metal coating in the shop, this coating shall be completed on site so as to be continuous over any welds, bolts and site rivets.

Specified protective treatment shall be completed after erection.

1906.6 Methods of Application

The methods of application of all paint coatings shall be in accordance with the manufacturer's written recommendation and shall be as approved by the Engineer. Spray painting may be permitted provided it will not cause inconvenience to the public and is appropriate to the type of structure being coated. Areas hard to gain access to for painting and areas shaded for spray application shall be coated first by brushing.

Oil based red lead primers must be applied by brush only, taking care to work into all corners and crevices.

The primer, intermediate and finishing coats shall all be applied so as to provide smooth coatings of uniform thickness. Wrinkled or blistered coatings or coatings with pinholes, sags, lumps or other blemishes shall not be accepted. Where the Engineer so directs, the coating shall be removed by abrasive blast cleaning and replaced at the Contractor's cost.

1906.7 Protective Coating System in Different Environments

Since the seriousness of the problem of corrosion depends upon atmospheric conditions and these vary enormously, there is no single protective system or method of application that is suitable for every situation.

However, as a guide, broad recommendations are given in Table 1900-3 for various types of coatings in various environmental conditions which should be complied with. Approximate life to first maintenance is also indicated and can be used as a guide.

Table 1900-3 Recommendations for Types of Protective Coatings

System	Environment
i) Wire brush to remove all loose rust and scale; 2 coats drying oil type primer, 1 under coat alkyd type paint; 1 finishing coat alkyd type. Total dry film thickness = 150 µm	Suitable for mild conditions where appearance is of some importance and where regular maintenance is intended. This system may deteriorate to a marked extent if it is exposed to moderate aggressive atmospheric conditions for long period
ii) Wire brush to remove all loose rust and scale; 2 coats drying oil type primer; 2 under coats micaceous iron oxide (MXO) pigmented phenolic modified drying oil. Total dry film thickness = 170 µm	Similar to (i) but where appearance is not very important provides longer life in mild condition. Will provide upto 5 years life to first maintenance in polluted inland environment
iii) Blast clean the surface; 2 coats of quick drying primer; undercoat alkyd type paint; 1 finishing coat alkyd type. Total dry film thickness : 130 – 150 µm	Compared to (i), this would provide a longer life in mild conditions and could be used in less mild situation e.g. inland polluted, where maintenance could easily be carried out at regular intervals
iv) Blast clean the surface; 2 coats of drying type oil primer; 1 undercoat micaceous iron oxide pigmented drying oil type paint. Total dry film thickness : 165–190 µm	Suitable for general structural steel work exposed to ordinary polluted inland environments where appearance is not of primary importance

v) Blast clean the surface; 2 coats of metallic lead pigmented chlorinated rubber primer, 1 undercoat of high build chlorinated rubber primer, 1 undercoat of high build chlorinated rubber; 1 finishing coat of chlorinated rubber. Total dry film thickness : 200 µm	Suitable for structures in reasonably aggressive conditions e.g. near the coast. Will provide long-term protection than (iv) in non-coastal situations. Also suitable for aggressive interior situations such as industrial areas.
vi) Blast clean the surface; 350 – 450 µm thickness coal tar epoxy.	Suitable for sea water splash zones or for conditions of occurrence of frequent salt sprays.
vii) Pickle; hot dip galvanised (Zinc). Total thickness : 85 µm	Suitable for steel work in reasonably mild conditions Life of 15-20 years before first maintenance could be expected in many situations
viii) Grit blast, hot dip galvanised. (Zinc). Total thickness = 140 µm	Provides a longer life than (vii) because of thicker zinc coating
ix) Grit blast; 1 coat of sprayed zinc/ aluminum followed by suitable sealer Total thickness = 150 µm	Expected to provide long term protection approx 15-20 years in aggressive atmosphere

1907 TESTS AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with relevant IS specifications and necessary test certificates shall be furnished. Additional tests, if required, shall be got carried out by the Contractor at his own cost.

The fabrication, furnishing, erecting, painting of structural steel work shall be in accordance with these specifications and shall be checked and accepted by the Engineer.

1908 MEASUREMENTS FOR PAYMENT

The measurements of this item shall be in tones based on the net weight of metal in the fabrication structure computed on the basis of nominal weight of materials.

The weight of rolled and cast steel and cast iron shall be determined from the dimensions shown on the drawings on the following basis :

- Rolled or cast steel : 7.84×10^{-3} kg/cu.cm.
- Cast Iron : 7.21×10^{-3} kg/cu.cm.

Weight of structural sections shall be nominal weight.

Weight of castings shall be computed from the dimensions shown on the drawings with an addition of 5 percent for fillets and over-runs.

Weight of weld fillets and the weight of protective coatings shall not be included.

Weight of rivet heads shall be computed by taking the weight of 100 snap heads as given in Table 1900-4.

When specially agreed upon, allowance for snap heads may be taken as a flat percentage of the total weight. This percentage may be taken as 3 percent or modified by mutual agreement.

Table 1900-4 Weight of Rivet Heads

Dia of Rivet as manufactured mm	Weight of 100 snap heads kg
12	1.3
14	2.1
16	3.4
18	4.45
20	6.1
22	8.1
24	10.5
27	15.0
30	20.5
33	27.2

The Contractor shall supply detailed calculation sheets for the weight of the metal in the fabricated structure.

No additions shall be made for the weight of protective coating or weld fillets.

Where computed weight forms the basis for payment, the weight shall be calculated for exact cut sizes of members used in the structure, deductions being made for all cuts, except for rivet holes. Additions shall be made for the rivet heads as mentioned above.

When specially agreed upon, the basis for payment may be the bridge weight complete, according to specifications included in special provision of the Contract.

1909 RATE

The contract unit rate for the completed structural steel work shall include the cost of all materials, labour, tools, plant and equipment required for fabrications, connections, oiling, painting, temporary erection, inspection, tests and complete final erection as shown on the drawings or as directed by the Engineer and as specified in these Specifications.

Open Foundations

2100

Open Foundations

2100 OPEN FOUNDATIONS

2101 DESCRIPTION

The work shall cover furnishing and providing plain or reinforced concrete foundation placed in open excavation, in accordance with the drawings and these Specifications or as directed by the Engineer.

2102 MATERIALS

Materials shall conform to Section 1000 of these Specifications.

2103 GENERAL

A method statement for construction indicating the following shall be submitted by the Contractor for approval of the Engineer, well in advance of the commencement of open foundation :

i) Sources of Materials

ii) Design, erection and removal of formwork

iii) Production, transportation, laying and curing of concrete

iv) Personnel employed for execution and supervision

v) Tests and sampling procedures

vi) Equipment details

vii) Any other point

Necessary arrangements for execution under water wherever necessary, shall be included in method statement.

Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark.

2104 WORKMANSHIP

2104.1 Preparation of Foundations

Excavation for laying the foundation shall be carried out in accordance with Section 300 of these Specifications. The last 300 mm of excavation shall be done just before laying of lean concrete below foundation.

In the event of excavation having been made deeper than that shown on the drawing or as ordered by the Engineer, the extra depth shall be made up with M15 concrete in case of foundation resting on soil and foundation grade concrete for foundations in rock, at the cost of the Contractor and shall be considered as incidental work. Special care shall be taken not to disturb the bearing surface. Open foundations shall be constructed in dry conditions and the Contractor shall provide for adequate dewatering arrangements to the satisfaction of the Engineer.

2104.2 Setting Out

The plan dimensions of the foundation shall be set out at the bottom of foundation trench and checked with respect to original reference line and axis. It shall be ensured that at no point the bearing surface is higher than the founding level shown on the drawing or as directed by the Engineer.

2104.3 Construction

A 100 m thick (minimum) layer of M15 concrete shall be provided above the natural ground to provide an even surface to support the foundation concrete. Before laying of lean concrete layer, the earth surface shall be cleaned of all loose material and wetted. Care shall be taken to avoid muddy surface. If any portion of the surface has been spoiled by over-wetting, the same shall be removed. Concrete M15 may be laid to the thickness of more than 100 mm, if required as per the direction of the Engineer. No construction joint shall be provided in the lean concrete.

No formwork is necessary for the lean concrete layer. Side formwork shall be used for foundation concrete work. Formwork for top of the foundation concrete shall also be provided, if its top has slopes steeper than 1 (vertical) to 3 (horizontal). When concrete is laid in slope without top formwork, the slump of the concrete shall be carefully maintained to ensure that compaction is possible without slippage down to slope of freshly placed concrete. In certain cases it may be necessary to build the top formwork progressively as the concreting proceeds up the slope. Reinforcement shall be laid as shown on the drawing.

Before laying foundation concrete, the lean concrete or hard rock surface shall be cleaned of all loose material and lightly moistened. Foundation concrete of required dimensions and shape shall be laid continuously upto the location of construction joint shown on the drawing or as directed by the Engineer.

Formwork and concrete shall conform to Sections 1500 and 1700 respectively of these Specifications. Furnishing and providing steel reinforcement shall conform to Section 1600.

The concrete surface shall be finished smooth with a trowel. The location of construction joint and its treatment shall be done as per requirements of Section 1700. Formwork shall

be removed not earlier than 24 hours after placing of concrete. Where formwork has been provided for top surface, the same shall be removed as soon as concrete has hardened. Curing of concrete shall be carried out by wetting of formwork before removal. After its removal, curing shall be done by laying not less than 10 cm of loose moistened sand, free from clod or gravel and shall be kept continuously moist for a period of 7 days.

Dewatering, where necessary for laying of concrete, shall be carried out adopting any one of the following procedures or any other method approved by the Engineer.

i) A pit or trench deeper than the foundation level as necessary may be dug beyond the foundation pit during construction so that the water level is kept below the foundation level.

ii) Water table is depressed by well point system or other methods.

iii) Use of steel/concrete caissons or sheet piling for creating an enclosure for the foundations, which can subsequently be dewatered.

No pumping of water shall be permitted for 24 hours from the time of placing the concrete.

In situation where foundations can not be laid dry or where percolation is too heavy to keep foundation strata dry, concrete may be laid under water only by tremie. In case of flowing water or artesian spring, the flow shall be stopped or reduced to the feasible extent at the time of placing the concrete.

Before backfilling is commenced, loose sand laid on foundation shall be removed and dispersed as directed by the Engineer.

All spaces excavated and not occupied by the foundation or other permanent works shall be refilled with earth upto surface of surrounding ground in accordance with Section 300. In case of excavation in rock, the annular space around foundation shall be filled with M15 concrete upto the top of rock.

The protective works, where provided shall be completed before the floods so that the foundation does not get undermined.

2105 TESTS AND STANDARS OF ACCEPTANCE

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

No point of the surface of the lean concrete in the case of foundation on soil or the surface of hard rock in the case of foundation on hard rock, shall be higher than the founding level shown on the drawing or as ordered by the Engineer. Levels of the surface shall be taken at intervals of not more than 3 metres centre-to-centre, subject to a minimum of nine levels on the surface.

2106 TOLERANCES

a)	Variation in dimensions	: +50 mm, –10
b)	Misplacement from specified position in plant	: 15 mm
c)	Surface irregularities measured with 3 m straight edge	: 5 mm
d)	Variation of levels at the top	: $\pm$ 25 mm

2107 MEASUREMENT FOR PAYMENT

Excavation in foundation shall be measured in accordance with Section 300, based on the quantity ordered or as shown on the drawing.

Lean concrete shall be measured in cubic metres in accordance with Section 1700, based on the quantity ordered or as shown on the drawing.

Concrete in foundation shall be measured in cubic metres in accordance with Section 1700, based on the quantity ordered or as shown on the drawing.

Reinforcement steel shall be measured in tonnes in accordance with Section 1600, based on the quantity ordered or as shown on the drawing.

2108 RATE

The contract unit rates for excavation in foundation, lean concrete and concrete in foundation and reinforcement steel shall include all works as given in respective sections of these Specifications and cover all incidental items for furnishing and providing open foundation as mentioned in this Section.

Sub - Structural

2200

Sub-Structure

2201 DESCRIPTION

The work shall cover furnishing and providing of masonry or reinforced concrete sub-structure in accordance with the drawings and as per these specifications or as directed by the Engineer.

2202 MATERIALS

Materials shall conform to Section 1000 of these Specifications.

2203 GENERAL

2203.1 A method statement for construction indicating the following shall be submitted by the Contractor for approval of the Engineer, well in advance of the commencement of sub-structure :

- i) Sources of Materials,
- ii) Design, erection and removal of formwork,
- iii) Production, transportation, laying and curing of concrete,
- iv) Personnel employed for execution and supervision,
- v) Tests and sampling procedures,
- vi) Equipment details,
- vii) Any other point.

2203.2 Arrangements for execution under water wherever necessary, shall be included in method statement.

2203.3 Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark.

2204 PIERS AND ABUTMENTS

2204.1 Masonry, formwork, concrete and reinforcement for piers and abutments shall conform to relevant sections of these specifications. In case of concrete piers, the number of horizontal construction joints shall be kept minimum. Construction joints shall be avoided in splash zones unless specially permitted by the Engineer and provided they are treated in accordance with special provisions. No vertical construction joint shall be provided. The work shall conform strictly to the drawings or as directed by the Engineer.

2204.2 In case of tall piers and abutments, use of slipform shall be preferred. The design, erection and raising of slipform shall be subject to special specifications which will be furnished by the Contractor. The concrete shall also be subject to additional specifications as necessary. All specifications and arrangements shall be subject to the approval of the Engineer.

2204.3 The surface of foundation/well cap/pile cap shall be scrapped with wire brush and all loose materials removed. In case reinforcing bars projecting from foundations are coated with cement slurry, the same shall be removed by tapping, hammering or wire brushing. Care shall be taken to remove all loose materials around reinforcements. Just before commencing masonry or concrete work, the surface shall be thoroughly wetted.

2204.4 In case of plain cement concrete substructure surface reinforcement at the rate of 2.5 kg per sq.m shall be provided in each direction. Spacing of bars for surface reinforcement shall not exceed 200 mm.

2204.5 In case of solid (non-spill through type) abutments, weep holes as shown on the drawings or as directed by the Engineer, shall be provided in conformity with Section 2706.

2204.6 The surface finish shall be smooth, except the earth face of abutments which shall be rough finished.

2204.7 In case of abutments likely to experience considerable movement on account of backfill of approaches and settlement of foundations, the construction of the abutment shall be followed by filling up of embankment in layers to the full height to allow for the anticipated movement during construction period before casting of superstructure.

2205 PIER CAP AND ABUTMENT CAP

2205.1 Formwork, reinforcement and concrete shall conform to relevant sections of these specifications.

2205.2 The locations and levels of pier cap/abutment cap/pedestals and bolts for fixing bearings shall be checked carefully to ensure alignment in accordance with the drawings.

2205.3 The surface of cap shall be finished smooth and shall have a slope for draining of water as shown on the drawings or as directed by the Engineer. For short span slab bridges with continuous support on pier caps, the surface shall be cast horizontal. The top surface of the pedestal on which bearings are to be placed shall also be cast horizontal.

2205.4 The surface on which elastomeric bearings are to be placed shall be wood float finished to a level plane which shall not vary more than 1.5 mm from straight edge

placed in any direction across the area. The surface on which other bearings (steel bearings, pot bearings) are to be placed shall be cast about 25 mm below the bottom level of bearings and as indicated on the drawings.

2206 DIRT WALL, RETURN WALL AND WING WALL

2206.1 Masonry, concrete and reinforcement shall conform to relevant sections of these specifications.

2206.2 In case of cantilever return walls, no construction joint shall generally be permitted. Wherever feasible, the concreting in cantilever return walls shall be carried out in continuation of the ballast wall.

2206.3 For gravity type masonry and concrete return and wing wall, the surface of foundation shall be prepared in the same manner as prescribed for construction of abutment. No horizontal construction joint shall be provided. If shown on drawing or directed by the Engineer, vertical construction joint may be provided. Vertical expansion gap of 20 mm shall be provided in return wall/wing wall at every 10 metre intervals or as directed by the Engineer. Weep holes shall be provided as prescribed for abutments or as shown on the drawings.

2206.4 Formwork, reinforcement and concrete in dirt wall shall conform to relevant sections of these specifications.

2206.5 The finish of the surface on the earth side shall be rough while the front face shall be smooth finished.

2206.6 Architectural coping for wing wall/return wall in brick masonry shall conform to section 1300.

2207 TESTS AND STANDARDS OF ACCEPTANCE

2207.1 The materials shall be tested in accordance with these specifications and shall meet the prescribed requirement.

2207.2 The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

2208 TOLERANCES IN CONCRETE ELEMENTS

a) Variation in cross-sectional dimensions : +10 mm, -5 mm

b) Misplacement from specified position in plan : 10 mm

c)	Variation of levels at the top	:	± 10 mm
d)	Variations of reduced levels of bearing areas	:	± 5 mm
e)	Variations from plumb over full height	:	± 10 mm
f)	Surface irregularities measured with 3 m straight edge		
	All surfaces except bearing areas	:	5 mm
	Bearing areas	:	3 mm

2209 MEASUREMENTS FOR PAYMENT

2209.1 Masonry in sub-structure shall be measured in cubic metres in accordance with Section 1300 or 1400, based on the quantities ordered or as shown on the drawings.

2209.2 Concrete in sub-structure shall be measured in cubic metres in accordance with Section 1700, based on the quantity ordered or as shown on the drawings. No deduction shall be made for weep holes.

2209.3 Steel in concrete of sub-structures shall be measured in tonnes, in accordance with Section 1600, based on the quantity ordered or as shown on the drawings.

2209.4 Weep holes shall be measured as per Section 2700, based on the quantity ordered or as shown on the drawings.

2210 RATE

The contract unit rates for masonry, concrete, reinforcement and weep holes shall include all works as given in respective sections of these specifications and cover all incidental items for furnishing and providing substructure as mentioned in these Specification.

2300

Concrete Superstructure

2301 DESCRIPTION

The work shall cover furnishing and providing of concrete super-structure in accordance with the drawings as per these specifications or as directed by the Engineer.

2302 MATERIALS

Materials shall conform to Section 1000 of these Specifications.

2303 GENERAL

2303.1 A method statement for construction, indicating the following, shall be submitted by the Contractor for approval of the Engineer, well in advance of the commencement of the construction of superstructure.

- i) Sources of Materials
- ii) Design, erection and removal of formwork
- iii) Production, transportation, laying and curing of concrete
- iv) Prestressing system, if applicable
- v) Personnel employed for execution and supervision
- vi) Tests and sampling procedure
- vii) Equipment details
- viii) Any other point

2303.2 Dimensions, lines and levels shall be set out and checked with respect to permanent reference lines and permanent bench mark so that the final product is in accordance with the drawings or as directed by the Engineer.

2303.3 The work shall conform to the following sections besides stipulations in this section with regard to specific type of construction :

i)	Formwork	Section 1500
ii)	Steel Reinforcement	Section 1600
iii)	Structural Concrete	Section 1700
iv)	Prestressing	Section 1800

Additionally, some of the common types of superstructure construction shall have features as discussed in this Section.

2304 REINFORCED CONCRETE CONSTRUCTION

2304.1 Solid Slabs

Where adjacent span of slab has already been cast, the expansion joint and filler board shall be placed abutting the already cast span which shall form the shutter on that slide of the new span to be cast. The whole of the slab shall be cast with reinforcement embedded for the road kerb and railings. No other construction joint shall be allowed except with the express permission of the Engineer.

Where wearing coat is required to be provided, after the deck slab has been cast, the surface of the slab shall be finished rough, but true to lines and levels as shown on the drawings, before the concrete has hardened. The areas of construction joints shall be treated in the prescribed manner.

The top of the slab shall be covered with clean moist sand as soon as the top surface ahs hardened. Curing shall be carried out as per Section 1700.

Where the slab is resting on bearings, the same shall be placed in position in accordance with the drawings, before casting of deck slab.

2304.2 RCC T-Beam and Slab

Provision of construction joint shall conform to the drawings or as per directions of the Engineer. No construction joint shall be provided between the bottom bulb and the web. If not indicated on the drawing, construction joint may be provided at the junction of the web and the fillet between the web and the deck slab with the permission of the Engineer.

The portions of deck slab near expansion joints shall be cast alongwith reinforcements and embedments for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer.

The surface finish of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete has hardened. Care shall be taken for setting of bearings as indicated on the drawings.

2305 PRESTRESSED CONCRETE CONSTRUCTION

2305.1 PSC Girder and Composite RCC Slab

PSC Girder may be precast of cast-in-situ as mentioned on the drawing or as directed by the Engineer. Girders may be post-tensioned or pre-tensioned. Where precast construction is required to be adopted, selection of casting yard and details of methodology and of

equipment for shifting and launching of girders shall be included in the method statement.

In case of cast-in-situ construction, the sequence of construction including side shifting of girders, if applicable, and placing on bearings shall be in accordance with the drawings.

The PSC girder constituting the top flange, web and the bottom flange shall be concreted in a single operation without any construction joint.

The portions of deck slab near expansion joints shall be cast alongwith reinforcements and embedments for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer.

The surface finish of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete had hardened. Care shall be taken for setting of bearings as indicated on the drawings.

2305.2 Box Girder

Box girders may be simply supported or continuous. Simply supported box girders shall have minimum construction joints as approved by the Engineer. In the case of continuous box girders the sequence of construction and location of construction joints shall strictly follow the drawings.

The box section shall be constructed with a maximum of one construction joint located in the web below the fillet between the deck slab and web. If permitted by the Engineer, one additional construction joint may be permitted and this construction joint shall be located in the web above the fillet between the soffit slab and web.

The portions of deck slab near expansion joints shall be cast alongwith reinforcements and embedments for expansion joints. For this purpose, the portion of deck slab near expansion joints may be cast in a subsequent stage, if permitted by the Engineer.

The surface finish of the deck slab shall be finished rough but true to lines and levels as shown on the drawings before the concrete has hardened. Care shall be taken for setting of bearings as indicated on the drawings.

2305.3 Cantilever Construction

Continuity of untensioned reinforcement from one segment to the next must be ensured by providing full lap length as necessary.

The design of the superstructure shall take into account the following aspects which form an integral part of the construction operations :

a) Stability against over-turning for each statical condition through which the assembly passes, shall be checked.

b) Stresses at each preceding segment joint with the addition of every segment or change of statical conditions shall be checked. The load of equipment as well as construction live load shall be taken into account.

c) Precambering of the superstructure during construction shall be done in such a manner that the finally constructed structure under permanent load attains the final profile intended in the drawings.

2306 TOLERANCES

2306.1 Precast Concrete Superstructure

Variation in cross-sectional dimensions :

a)	upto and including 2m	:	± 5 mm
	over 2m	:	± 5 mm
b)	Variation in length overall and between 10mm bearings	:	shall not exceed ± length or ± 0.1 per cent of the span length, whichever is lesser
c)	Permissible surface irregularities when measured with a 3 m straight edge or template	:	5 mm

2306.2 Cast-in-Situ Superstructure

a)	Variations in thickness of top and for box girders, top and bottom flange for T-girders or slabs	:	-5 mm to +10 mm
b)	Variations in web thickness	:	-5 mm to +10 mm
c)	Variations in overall depth or width	:	± 5 mm
a)	Variation in length overall and length between bearings	:	shall not exceed ± 10mm or ±0.1 per cent of the span length, whichever is lesser
e)	Permissible surface irregularities	:	5 mm measured with a 3 m straight edge or template

2307 TEST AND STANDARDS OF ACCEPTANCE

The materials shall be tested in accordance with these specifications and shall meet the prescribed criteria.

The work shall conform to these specifications and shall meet the prescribed standards of acceptance.

2308 MEASUREMENT FOR PAYMENT

Concrete in superstructure shall be measured in accordance with Section 1700, based on the quantity ordered or as shown on the drawings.

Steel reinforcement (untensioned) in superstructure shall be measured in accordance with Section 1600, based on the quantity ordered or as shown on the drawings.

High tensile steel (prestressing) in superstructure shall be measured in accordance with Section 1800, based on the quantity ordered or as shown on the drawings.

2309 RATE

The contract unit rates for concrete, steel reinforcement (untensioned) and high tensile steel (prestressing) shall include all works as given in respective sections of these specifications and cover all incidental items for furnishing and providing superstructure as mentioned in this section.

2400

Surface and Sub-surface Geotechnical Exploration

2401 DESCRIPTION

2401.1 The objective of sub-surface exploration is to determine the suitability or otherwise of the soil or rock surrounding the foundation and soil parameters and rock characteristics for the design of foundation by in-situ testing or testing of samples/cores taken out of exploration. The sub-surface exploration shall be planned in such a way that different types of soil upto the desired depth and their profile for the full proposed length of the bridge can be recorded and other information such as mechanical and physical properties like grain-size distribution sensitivity, any existence of deleterious material in soil or ground water, etc., are determined alongwith soil parameters and rock characteristics. The sub-surface exploration shall also also thro light on porosity of rock and subsidence due to mining, ground water level, artesian condition, if any, likely sinking and driving effort, likely constructional difficulties, etc.

Field Investigation

Field investigations of sub-surface has usually three phases :

Reconnaissance
Preliminary Explorations
Detailed Explorations

2401.2.1 Reconnaissance includes a review of available topographic and geological information, aerial photographs and data from previous investigations and site examination.

2401.2.2 Preliminary investigation shall include the study of existing geological information, previous site reports, geological maps, air photos, etc. and surface geological examination. For large and important structures the information may be supplemented by geophysical methods. In some cases where no previous sub-strata data are available, exploratory geophysical investigation may need to be supplemented by resorting to a few bore-holes. These will help to narrow down the number of sites under consideration and also to locate the most desirable location for detailed sub-surface investigation like bore or drill holes, sounding probes, etc.

2401.2.3 The scope of detailed investigation for bridges may be decided based on data obtained after preliminary investigation. Based on data obtained after preliminary investigations, the bridge site, type of structure with span arrangement and the location and type of foundations, shall be tentatively decided. Thereafter, the scope of detailed investigation including the extent of exploration, number of bore-holes, type of soundings, type of tests, number of tests, etc., shall be decided, so that adequate data considered to be necessary for the detailed design and execution, are obtained.

2401.2.4 The width of exploration : One purpose of detailed exploration for high embankments is to ascertain the average shear strength of each strata. The other purpose is to ascertain the compressibility of the clayey strata. It is, therefore, necessary that detailed and well illustrated description of the characteristics of stratification should be prepared. After the general shape and trend of the boundaries of the various soil deposits have been determined and rough assessment of their strength has been made by sub-surface sounding, with or without sampling in exploratory boring, the location of bore-hole(s) for undisturbed sampling shall be decided. At least one representative undisturbed sample should be collected from each strata. When the homogeneous strata is very thick, one representative sample shall be collected for each 3 m thickness of the strata.

2401.3 Soil investigation for foundations shall contain a programme for boring and retrieval of samples. The field work shall consist of excavation, drilling of bore-holes for the purposes of collection of undisturbed and disturbed samples, standard penetration tests, in-situ vane tests, static and dynamic cone penetration tests, other filed tests, as specified by the Engineer and preparation of bore-logs. Collection and preservation for testing of disturbed and undisturbed samples from boreholes, borrow pits, etc., as specified by the Engineer shall form a part of the above. All in-situ tests shall be supplemented by laboratory investigations. Relevant Indian Standards such as IS:1498, IS:1888, IS:1892, IS:2131, IS:2132, IS:2720, IS:4434 and IS:4968 and Appendix I of IRC:78, etc. shall be followed for guidance.

2401.4 The soundings by dynamic method shall be carried out in bore-holes using a standard sampler as specified in IS:2131.

2402 PRELIMINARY INVESTIGATION

2402.1 Foundations

2402.1.1 Preliminary exploration shall be carried out to determine the soil profile showing the boundaries between the different soil types and between loose and dense parts in the same type of deposits. For guidance reference may be made to IRC:75. For this purpose, as a first step, a suitable type of sub-surface sounding (e.g. static or dynamic cone penetration test) shall be carried out. As man soundings as necessary should be made, until the penetration data is complete enough to leave no doubt concerning the general shape and the trend of boundaries of the various soil deposits. Exploratory drill holes should then be made at one or two locations where average condition prevails and near those few points where the penetration diagrams indicate maximum deviations from the average.

2402.1.2 The exploration shall cover the entire length of the bridge and also extend at either side for a distance about twice the depth below bed of the last main foundations. If there is any necessity for designing investigation for approaches particularly on soft soil or

with high embankment or there is a possibility of considering alternatives between viaduct or earthen embankment, the extended length and location of the borings beyond the proposed location of abutment should be determined and executed.

2402.1.3 The depth of exploration should be at least 1½ times minimum width of foundation below the proposed foundation level. Where such investigation end in any unsuitable or questionable foundation material the exploration shall be extended to a sufficient depth into firm and stable soils or rock but not less than found times the minimum depth of foundation below the earlier contemplated foundation level. In case of good sound rock the stipulation of minimum depth may be decreased based on difficulty to conduct core drilling and the minimum depth may be restricted to 3 metres.

2402.2 Guidebund and Embankment

The depth of exploration should include all strata likely to affect stability of the embankment, guide bund and/or cause undesirable settlement. In general, the requirement of settlement governs the depth of exploration for high embankments in particular. However, borings can be terminated at shallower depths when firm strata or bed rock is encountered. Ordinarily, the boring shall be taken to a depth of at least 1.5 times the height of embankment and guidebund. However, where highly compressible strata are encountered, the boring may have to be taken deeper. In order to ensure that firm strata is sufficiently thick, the boring should extend 3 metre into the firm strata.

2403 DETAILED EXPLORATION

2403.1 The exploration shall cover the entire length of the bridge and also extend at either end for a distance of about twice and depth below bed of the last main foundation to assess the effect of the approach embankment on the end foundations. Generally the sub-surface investigations (preliminary and detailed) for bridges shall extend to a depth below the anticipated foundation level equal to about one and a half times the width of the foundation. However, where such investigations end in any unsuitable or questionable foundation material, the exploration shall be extended to a sufficient depth into firm and stable soils or to rock.

2403.2 The type and extent of exploration shall be divided into the following groups as per requirement of foundation design and likely method of data collection :

Foundation requiring shallow depth of exploration
Foundation requiring large depth of exploration
Fills behind abutments and protection works

Location Boring

Where the data made available by detailed exploration indicates appreciable variation or

where variations in a particular foundation are likely to appreciably affect the construction (specially in case of bridge foundations resting on rock), it will be necessary to resort to additional bores/soundings to establish complete profile of the underlying strata. The additional borings/soundings shall be decided depending upon the extent of variation at a particular foundation location and should cover the entire area of the particular foundation.

Construction Stage Exploration

Whenever a change in the sub-soil strata/rock profile is encountered during construction, explorations shall be resorted to establish the correct data for further decisions.

2403.5 Logging of bore-holes by radio-active methods shall be done for detailed investigations as specified in the contract or in special provisions.

2403.6 For bridge works, the investigations shall be comprehensive enough to enable the designer to estimate or determine the following :

i) the engineering properties of the soil/rock,
ii) the location and extent of soft layers and gas pockets, if any, under the hard founding strata,
iii) the geological condition like type of rock, faults, fissures or subsidence due to mining, porosity etc.,
iv) the ground water level,
v) artesian conditions, if any,
vi) quality of water in contact with the foundation,
vii) the depth and extent of scour,
viii) suitable depth of foundation,
ix) the bearing capacity of the foundation,
x) probable settlement and probable differential settlement of the foundations,
xi) likely sinking or driving effort, and
xii) likely construction difficulties.

2404 EXPLORATION FOR BRIDGE FOUNDATIONS RESTING ON ROCK

2404.1 Investigation and interpretation of data for rock is a specialised work. To arrive at the characteristic strength of rock mass, reliance shall be placed more on in-situ tests in comparison to laboratory tests. An engineering geologist shall also be associated in the exploration programme.

2404.2 Identification and classification of rock types for engineering purposes may in general be limited to broad, basic geological classes in accordance with accepted practice. Strength of parent rock alone is of limited value because overall characteristics

depend considerably on character, spacing and distribution of discontinuities of the rock mass, such as the joints, bedding planes, faults and weathered seams. An important factor affecting the behaviour is the weathered zone at top.

2404.3 Basic Information Required from Explorations

i) Depth of rock strata and its variation over the site,
ii) Whether isolated boulder or massive rock formation,
iii) Extent and character of weathered zone,
iv) Structure of rock – including bedding planes, faults, fissures, solution cavities etc.,
v) Properties of rock material-strength, geological formation, etc.,
vi) Erodibility of rock to the extent possible,
vii) Colour of water.

2404.4 Exploration Programme

If preliminary investigations have revealed presence of rock within levels where the foundation is to rest, it is essential to take up detailed investigation to collect necessary information mentioned in clause 2404.3. The exploratory bore-hole shall be drilled into the rock to a depth of about 3 metres to distinguish a boulder from a continuous rock formation.

2404.5 The extent of exploration shall be adequate enough to give a complete picture of the rock profile both in depth and across the channel width to assess the constructional difficulties in reaching the foundation levels.

2404.6 The depth of boring in rock depends primarily on local geology, erodibility of the rock, extent of structural loads to be transferred to foundation etc. Normally, it shall pass through the upper weathered or otherwise weak zone, well into the sound rock. Minimum depth of boring in sound rock shall be 3 metres.

2404.7 Detailed Investigation for Rock

2404.7.1 This cover sounding, boring and drilling. An adequate investigation programme shall be planned to cover the whole area for general characteristics and in particular the foundation location , to obtain definite information regarding rock-depth and its variation over the foundation area. The detailed programme of exploration will depend on the type and depth of over-burden, the size and importance of the structure, etc. To decide this, geophysical methods adopted at the preliminary investigation stage will be helpful, this data being supplemented by sounding, bore-holes and drill holes.

2404.7.2 Drilling through rock is a very specialised work and every care shall be taken to notice and record any small change during drilling. The time required to drill through a certain depth, amount of core recovery, physical condition, length of pieces of core, joints, colour of water residue, weathering and evidence of disturbance and other effects shall be carefully noticed and entered in the drilling log. For guidance, IS:5313 may be referred to. The data shall be prescribed in accordance with IS:4464.

2404.7.3 The cores shall be stored properly in accordance with IS:4078.

2404.7.4 The rock cores obtained shall be subjected to following laboratory tests:

i) Visual identification for texture, structure, composition, colour and grain size.

ii) Laboratory tests shall be done for specific gravity, porosity and moisture content.

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2404.7.5 In-situ tests shall be made in accordance with IS:7292; IS:7317; and IS:7746. In addition, laboratory tests can also be made on samples.

2404.7.6 Use of in-situ tests for measuring strength and deformation characteristics shall be made. Use of bore-hole photography will be desirable to evaluate the presence of faults, fissures or cavities, etc.

2404.8 Special Cases

2404.8.1 Investigation for conglomerate : A drill hole shall be made same as for rock. The samples collected shall be subjected to suitable tests depending upon the material, special care shall be taken to ascertain erodibility of the matrix. Where possible, specially for shallow foundation, Plate Load Test shall be conducted.

2404.8.2 Investigation for laterites : The investigation shall be generally similar to that required for cohesive soils, use of penetration tests shall be preferred, if suitable correlation charts are available. This may be static or dynamic penetration tests or vane shear tests. In the case of hard laterite, recourse may have to be made to core drilling as for soft rocks. For laterites at shallow depths, use of Plate Load Test may be advantageous.

2404.9 Caution

2404.9.1 The interpretation of laboratory results on rock samples depends upon the relationship of the specimens tested to the overall rock characteristics, enumerated in Appendix 1 of IRC:78. For this purpose, care shall be exercised in the choice of specimen size and its orientation in relation to the joint pattern.

2404.9.2 In some cases, the foundation behaviour will be dominated by a possible mode of failure involving movement along some joint surface, fissures or weak layer within a generally strong rock system and also by possible weathering. In-situ shear tests may be conducted wherever feasible, as such tests are likely to give more representative data than the shear tests conducted on core samples.

2404.10 Presentation of Data

The data shall be given in diagrammatic form in 3 sheets giving the following details :

Sheet 1 : Plan showing the position of bore-holes clearly marked so as to fix the position at a future date.

Sheet 2 : This shall contain the bore-log chart and test results of the samples separately for each bore-hole/pit etc.

Sheet 3 : This shall contain pictorial representation of the bore-log data to get an overall picture of the soil profile at the cross-section of the river.

NOTE : For guidance, refer to IRC:78

2405 BORING

Boring shall be done by any of the following methods depending on the soil type and types of samples required for the investigation.

i) Auger Boring

ii) Shell and Auger Boring

iii) Percussion Boring

iv) Wash Boring

v) Rotary Boring

For preliminary and detailed sub-surface investigation only rotary drills shall be used. The casing shall also be invariably provided with diameters not less than 150 mm upto the level of rock, if any. However, use of percussion or wash boring equipment shall be permitted only to penetrate through bouldery or gravelly strata for progressing the boring but not for the collection of samples. While conducting detailed borings, the resistance to the speed of drilling i.e. rate of penetration, core loss, etc., as already specified in Appendix 3 of IRC:78 shall be carefully recorded to evaluate the different types of strata and to distinguish specially sand from sandstone, clay from shale, etc.

2406 RECORDS OF BORINGS AND TRIAL PITS

2406.1 The field records for the preliminary and detailed exploration shall contain the date when the boring was made, the location of the boring with reference to a permanent system of co-ordinates and the elevation of the ground surface with respect to a permanent bench mark. They shall include elevation at which the water table and the upper boundary of each of the successive soil strata were encountered, the investigator's classification of the layer on the basis of general information obtained from field examination (refer to Appendix 2.1 of IRC:75) and the value of the resistance obtained by means of Standard Penetration Test. The type of tools used for borings shall be recorded. If the tolls were changed, the depth at which the change was made and the reason thereof shall also be noted. Incomplete and abandoned borings shall be described with no less care than successfully completed drill holes. The notes shall contain everything of significance observed on the job such as the elevation at which wash water was lost from the hole.

2406.2 For all borings and trial pits, necessary information as detailed below shall be given. A site plan showing the disposition of the bore holes shall also be attached :

a) Agency

b) Location with reference map

c) Pit/Bore-hole number

d) Reduced level (R.L.) of ground surface or other reference point

Dates of starting and completion

Name of supervisor

Scales of plans and sections

Dimensions, methods of advancing exploration such as by hand tools, blasting, boring, etc.

General description of strata met with the RLs at which they are met

Position and altitude of contacts, faults, strong joint, slicken sides, etc.

Inflow of water, methods of controlling the water, required capacity of pumps for dewatering

The level at which the sub-soil water is met with

Dip and strike of bedding and of cleavage

Visual description of strata

Results of field tests e.g. SPT, in-situ vane shear test etc.

Any other information and remarks.

2406.3 Upon removal of sampling tube, the length of the sample in the tube and the length between the top of the tube and the top of the sample in the tube shall be measured and recorded.

2407 METHODS OF SAMPLING

There are two types of samples viz. (a) Disturbed sample (b) Undisturbed sample. The usual methods for sampling conforming to IS:1892 and IS:2132 are given below :

<table>
<tr><th>Nature of Ground</th><th>Type of Sample</th><th>Method of Sampling</th></tr>
<tr><td>Soil</td><td>Disturbed</td><td>Hand Samples
Auger Samples
Shell Samples</td></tr>
<tr><td rowspan="3">Rock</td><td>Undisturbed</td><td>Hand Samples
Tube Samples</td></tr>
<tr><td>Disturbed</td><td>Wash samples from
Percussion or rotary drilling</td></tr>
<tr><td>Undisturbed</td><td>Cores</td></tr>
</table>

2408 PROCEDURE FOR TAKING SAMPLES

2408.1 For proper identification of sub-surface material, sample should be recovered containing all the constituents of the materials in their proper proportion. In clayey deposits such samples could be collected by split spoon samplers. In the case of sandy deposits, sampling spoons shall be fitted with suitable devices for retaining samples. All data required for soil identification (Appendix 2.1 of IRC:75) should be collected from the samples so extracted when undisturbed samples, which are more desirable for collection of some of the data, are not available. Penetration test should be carried out with the standard split-spoon sampler or penetrometers if the soil is coarse grained. When it is known in advance that the soil profile is fairly regular, preliminary and detailed investigation may be combined. Tube samplers can be used in place of split spoon samplers for collecting samples in clayey strata.

2408.2 Disturbed Soil Samples

2408.2.1 Disturbed samples of soil shall be obtained in the course of excavation and boring. For procuring samples from below the ground water level, where possible, special type of sampler shall be used. Where Standard Penetration Test is conducted,

representative samples shall be obtained from the split spoon. While collecting disturbed samples from borrow areas it shall be ensured that the samples collected represent all types of borrow materials to be used in the construction of embankment and sub-grade.

2408.2.2 The size of sample generally required shall be as given in Table 2400-1.

Table 2400-1 Size Of Soil Sample Required

S. No.	PURPOSE OF SAMPLE	SOIL TYPE REQUIRED Kg	WEIGHT OF SAMPLE
1.	Soil identification, natural moisture content tests, mechanical analysis and index properties, chemical tests	Cohesive soils sands and Gravels	1 3
2.	Compression tests	Cohesive soils and sand	12.5
3.	Comprehensive examination of construction material and borrow area soil including soil stabilization	Cohesive soils and sands Gravelly soil	25 – 50 50 - 100

2408.2.3 While taking out disturbed soil samples, Standard Penetration Test may also be conducted to find out the bearing capacity of the sub-soils at specified levels.

2408.3 Undisturbed Soil Samples

2408.3.1 The location of the bore-hole shall be as indicated on the drawing or given by the Engineer.

The depth of the bore-hole shall be as indicated on the drawing or shall be governed by the criteria given therein or as directed by the Engineer.

2408.3.2 Samples shall be obtained in such a manner that their moisture content and structure do not get altered. This may be ensured by careful protection and packing and by use of correctly designed sampler.

2408.3.3 Standard Penetration Test may have to be conducted in each case to obtain additional data as directed by the Engineer. In soft clay, in-situ vane shear test as per IS:4434 may have to be conducted. Where all the three operations have to be carried out in one layer, the sequence shall be undisturbed soil sampling followed by in-situ vane shear test, followed by Standard Penetration Test.

2408.3.4 For compression test samples, a core of 40 mm diameter and about 150 to 200 mm length may be sufficient, but for other laboratory tests, a core of 100 mm diameter

and 300 mm length shall be taken as far as possible, unless otherwise specified by the Engineer.

2408.3.5 The upper few millimeters of both types of sample shall be rejected as the soil at the bottom of the bore hole usually gets disturbed by the boring tools.

2408.4 Rock Samples

2408.4.1 Disturbed samples : The sludge from percussion borings or from rotary borings which have failed to yield a core, shall be collected for a disturbed sample. It may be recovered from circulating water by settlement in a trough.

2408.4.2 Undisturbed samples : Block samples taken from the rock formation shall be dressed to a size of about 90 x 75 x 50 mm.

For core samples – cores of rock shall be taken by means of rotary drills fitted with a coring bit with core retainer, if warranted.

2408.4.3 In case of rock at shallow depths which can be conveniently reached test pits or trenches are the most dependable and valuable methods since they permit a direct examination of the surface, the weathered zone and presence of any discontinuities. It is also possible to taken representative samples for tests. For guidance, IS:4453 may be referred to.

2409 PROTECTION, HANDLING AND LABELLING OF SAMPLES

2409.1 Care shall be taken in handling and labeling of samples so that they are received in a fit state for examination and testing and can be correctly identified as coming from a specified trial pit or boring.

2409.2 The disturbed material in the upper end of the tube shall be completely removed before applying wax for sealing. The length and type of sample so removed should be recorded.

2409.3 The soil at the lower end of the tube shall be reamed to a distance of about 20 mm. After cleaning, both ends shall be sealed with wax applied in a way that will prevent was from entering the sample. Wax used for sealing should not be heated to more than a few degrees above its melting temperature. The empty space in the samplers, if any, should be filled with moist soil, saw dust, etc., and the ends covered with tight fitting caps.

2409.4. Labels giving the following information should be affixed to the tubes :

a) Tube number
b) Job designation
c) Sample location
d) Boring number
e) Sample number
f) Depth
g) Penetration
h) Gross recovery ratio

The tube and boring numbers should be marked in duplicate.

Duplicate markings of the boring number and sample number on a sheet which will not be affected by moisture should be enclosed inside the tube.

2410 TESTS FOR EXPLORATION OF SHALLOW FOUNDATIONS OF BRIDGES

2410.1 Test pits or trenches are the most dependable and valuable methods or exploration since they permit direct visual examination and more reliably the type of soil and their stratification. This will also allow in-situ tests like plate bearing tests, shear tests and uni-axial jacking tests, etc.

2410.2 Tests shall be conducted on undisturbed samples, which may be obtained from open pits. The use of Plate Load Test (as per IS:1888) is considered desirable to ascertain the safe bearing pressure and settlement characteristics. A few exploratory bore holes or soundings shall be made to safeguard against presence of weak strata underlying the foundation. This shall extend to a depth of about 1½ times the proposed width of foundation.

The laboratory results shall correlate with in-situ tests like Plate Load Tests and Penetration Test results.

2411 TESTS FOR EXPLORATION FOR DEEP FOUNDATIONS OF BRIDGES

2411.1 The tests to be conducted at various locations for properties of soil, etc., are different for cohesive and cohensionless soils. These are enumerated below and shall be carried out, wherever practicable, according to soil type.

2411.1.1 Cohesionless soil

a) Classification tests, density, etc.

b) Field tests.

- Plate Load test as per IS:1888
- Dynamic Penetration test as per IS:2131 and Use of Dynamic Cone penetration test as per IS:4968 (Part 1 or Part 2) may be conducted where considered appropriate.

c) Laboratory tests : Shearing strength test – triaxial or box shear test – in case of the possibility of rise of water table, the tests shall be done on saturated samples.

2411.1.2 Cohesive soils

a) Classification tests, density, etc.

b) Field tests :

- Plate Load Test.
- Unconfined Compression Test as per IS:2720 (Part 10).
- Vane Shear Test as per IS:4434.
- Static Cone Penetration Test (IS:4968 Part 3).

c) Laboratory tests : Shearing strength test – triaxial tests (IS:2720 Part 9). Consolidation Test (IS:2720 Part 15).

Note : Where dewatering is expected, samples may be tested for permeability (IS:2720 Part 17).

2411.2 The sub-surface exploration for bridge works can be divided into 3 zones:

i) between bed level and upto anticipated maximum scour depth (below H.F.L.)

ii) from the maximum scour depth to the foundation level.

iii) from foundation level to about 1½ times the width of the foundation below it.

2411.3 The sub-soil water shall be tested for chemical properties to ascertain the hazard of deterioration to foundations. Where dewatering is expected to be required, permeability characteristics shall be determined.

2411.4 For the different zones categorized in para 2411.2 the data required, such as soil classification, particle size distribution, shearing strength characteristics, method of sampling disturbed and undisturbed samples, testing, including particle size distribution, shear strength, unconfined compression test shall be complied with.

2412 TESTING OF MATERIAL FOR GUIDE BUND AND HIGH EMBANKMENT AND ITS FOUNDATIONS

2412.1 The soil properties for the embankment foundation shall be as specified in particular specifications and shall be got verified prior to construction operation. IN case the actual soil properties do not match the particular specification, then embankment design shall be revised.

2412.2 Field investigation for the embankment material should be carried out to collect general information as indicated in IRC:75. For details refer to Clause 305.

Field investigations for sub-soil strata shall consist of taking minimum two bore holes for each approach to a bridge along centre line of the alignment at a distance of 50 m and 120 m behind the abutment positions on both sides. The depth of bore holes below the ground level may ordinarily be 2.5 times the maximum height of the embankment subject to minimum depth of 20 m. This walled sampling tubes of 10 mm internal diameter and 450 mm minimum length conforming to IS:2132 shall be used for collecting undisturbed samples from bore-holes at an interval of 2.5 to 3.5 m. Standard penetration test should be conducted immediately after undisturbed sample is collected.

2412.3 In addition to the relevant identification tests, mentioned in IRC:75, it shall be necessary to conduct some of the following tests on the undisturbed samples collected from the sub-strata. The choice of test is primarily determined by the type of soil, type of stability analysis (vide Table 2400-2), availability of apparatus and cost of investigation.

2412.4.2 In addition to the above, there is need for shear strength tests on compacted samples of the fill material. For this purpose, the relative compaction should be 95 per cent of the Standard Proctor maximum dry density and moisture content, same as that likely to prevail in the embankment during the period covered by the stability analysis or to be used in the field during construction. Undrained test shall be run on cohesive soils and shear strength parameters should be ascertained for the ranges of normal pressures which are likely to be experienced in the field. In cases where effective stress analysis is required to be done, pore-pressure measurements should also be made during the undrained tests and effective strength and pore-pressure parameters should be found out. For fill material of cohesionless soils, a direct shear box test (IS:2720-Part 13) may be conducted to ascertain shear strength of soil.

Table 2400-2 Shear Strength Tests For Stability Analysis

S. No.	Stage in Life of embankment	Strength Parameters	Shear Test	Type of Analysis
1.	(a) During construction or immediate post-construction	c_{uu}, ϕ_{uu}	Unconsolidated undrained triaxial shear test on undisturbed samples	Total stress analysis
1	(b) — do —-	S_u	Unconfined compression test in laboratory or vane shear test	— do —-
1	(c) During construction or immediate	$C\phi'$	Consolidated undrained test with post-construction pore-pressure measurement on as compacted soil samples of embankment materials and on undisturbed samples	Effective stress analysis
2.	Long term stability	$C\phi'$	— do —-	— do —-

2412.4 Laboratory Investigations of Embankment Material

2412.4.1 The following tests should be conducted on representative samples of embankment material :

S.No.	Test	Test Method
i)	Gradation Test (Sieve Analysis)	IS:2720 (Part 4)
ii)	Atterberg Limit Test	IS:2720 (Part 5)
iii)	Standard Proctor Test	IS:2720 (Part 7)
iv)	Natural Moisture Content	IS:2720 (Part 2)

2412.4.2 In addition to the above, there is need for shear strength tests on compacted samples of the fill material. For this purpose, the relative compaction should be 95 percent of the Standard Proctor maximum dry density and moisture content, same as that likely to prevail in the embankment during the period covered by the stability analysis

or to be used in the field during construction. Undrained test shall be run on cohesive soils and shear strength parameters should be ascertained for the ranges of normal pressures which are likely to be experienced in the field. In cases where effective stress analysis is required to be done, pore-pressure measurements should also be made during the undrained tests and effective strength and pore-pressure parameters should be found out. For fill material of cohesionless soils, a direct shear box test (IS:2720-Part 13) may be conducted to ascertain shear strength of soil.

2412.4.3 The results of reconnaissance, field and laboratory investigations for embankments shall be consolidated into a well-knit report. The record of findings and recommendations, if any, may be presented in the form of written test, graphs, figures and tables, as appropriate for different types of data and findings.

Information and data to be contained in the report should include general location map, pertinent geological information on reconnaissance observations, sub-soil profile (Fig. 2.1 of IRC:75), boring logs and summary of sub-soil properties (Fig. 2.2 of IRC:75), graphs and tables related to laboratory investigations, results of borrow area investigations (Fig. 2.3 of IRC:75) and recommendations, if any.

The undisturbed samples shall be collected from each layer of sub-soil unless the stratum is such that undisturbed samples cannot be collected using ordinary sampler. Where indicated by the Engineer, undisturbed samples shall be collected using piston sampler or core-cutter or such special devices. In thick layers undisturbed samples shall be collected at 3 m interval.

2413 MEASUREMENT FOR PAYMENT

In case of bridge and road structures, the work of boring and trial pits shall be considered as incidental to the foundation works and nothing extra shall be paid unless otherwise specified in the contract. In cases where it is specified to be paid separately, like contract for soil investigation, the work shall be measured in running metres for boring, in cubic meters for trial pits, in number of samples for collection of disturbed and undisturbed samples and in number of tests for each type of test.

2412 RATE

The contract unit rate shall include the cost of all labour, materials, tools and plant and equipment required for doing the boring or making pits as per these specifications, taking out and packing the samples, sending and getting them tested in approved laboratories and making available the test report as specified or directed by the Engineer inclusive of all incidental costs to complete the work as per the specifications.

2500

River Training Work and Protection Work

2501 DESCRIPTION

River training and protection work shall include construction of guide bunds, guide walls, bank protection, flooring and approach embankment protection as required for ensuring safety of the bridge structure and its approaches against damage by flood/flowing water. Construction of various components shall conform to IRC:89 and these specifications or as directed by the Engineer.

2502 GUIDE BUND

2502.1 This work shall consist of construction of embankment of guide bund and provision of pitching/rivetment on slopes, apron, toe protection, curtain walls etc. as indicated on the drawing in accordance with these specifications or as approved by the Engineer.

The provisions given hereunder are applicable only to guide bunds for bridges across alluvial rivers. Guide bunds for bridge across submontane rivers shall call for supplemental specifications.

2502.2 The alignment and layout of guide bund shall be as indicated on the drawing or as approved by the Engineer. The construction of embankment for guide bund shall conform to provisions of Section 300 of these Specifications. Pitching, filter underneath pitching and turfing, apron, toe protection, curtain walls, etc., shall be as per these specifications.

2502.3 Guide bunds shall generally be made of locally available materials from the river bed preferably cohesionless materials. Trial pits shall be taken in borrow holes to examine suitability of soil for construction and also to decide the types of earth moving machinery to be arranged. The borrow pits should be sufficiently away from the location of the launching apron. No borrow pits should be dug on the river side of the guide bunds.

Construction of guide bund shall be taken in hand alongwith the construction of the bride. Every effort shall be made to complete the work of the guide bund in one working season. Where there is any doubt about completion of the whole guide bund within one working season, suitable measures shall be planned and executed for protection of completed work. In such cases the construction of guide bund shall be started from abutment towards upstream.

2502.4 Construction of apron and pitching of the guide bunds shall generally conform to clause 2503 and 2504 of these Specifications. Sufficient length of pit along the guide bund shall be ready within one to two months of commencement of work so that the placing of stones in the apron and in the slope pitching can be commenced. As a guideline, earth work should be completed within 80 per cent of working season and about 70 per cent

working season shall be available for laying apron and pitching. No portion of the guide bund should be left below HFL before the onset of monsoon. Bottom of apron pit shall be as low as permitted by sub-soil water/lowest water level. Sufficient labour and appropriate earth moving machinery and trained staff shall be deployed in construction.

2502.5 The Contractor shall furnish his planning for approval of the Engineer regarding transport of stones from the quarries to the site of work taking into account the quantities of stone required to be transported every day, train/truck, etc., deployed, available ferry or boats and labour available for loading and unloading and for laying within the time frame for construction of guide bund. Adequate reserve of stones should be maintained for major works as decided by the Engineer. Reserve stones shall be stacked far away from the main channel of the river.

2502.6 Where the alignment of guide bund or the approach embankment crosses s branch channel of the river, the branch channel may be either diverted to the main channel of the river with the help of spurs, etc. or closed by a properly designed closing dyke or closure bund before taking up construction of guide bund.

2503 APRON

2503.1 General

This work shall consist of laying boulders directly or in wire crates on the bed of rivers for protection against scour.

Where the required size of boulders are not available economically, cement concrete blocks of equivalent weight shall be used. The grade of concrete shall be M 15 nominal mix. (This holds good for pitching on slopes and flooring also). Cement concrete block shall be preferred where practicable.

This stones used in apron shall be sound, hard, durable and fairly regular in shape. Stone subject to marked deterioration by water or weather shall not be used.

Quarry stones are preferable to round boulders as the latter roll off easily. Angular stones fit into each other better and have good interlocking characteristics.

Where the required size stones are not economically available, cement concrete blocks in M15 grade conforming to Section 1700 or stones in wire crates in combination may be used in place of isolated stones of equivalent weight. Cement concrete blocks will be preferred, wherever practicable.

2503.2 Laying Boulder Apron

The size of stone should conform to clause 5.3.7.2 of IRC:89.

The size of stone shall be as large as possible. In no case any fragment shall weigh less than 40 kg. The specific gravity of stones shall be as high as possible and it shall not be less than 2.65.

To ensure regular and orderly disposition of the full intended quantity of stone in the apron, template cross walls in dry masonry shall be built about a metre thick and to the full height of the specified thickness of the apron at intervals of 30 metres all along the length and width of the apron. Within these walls, the stone then shall be hand packet.

The surface on which the apron is to be laid shall be leveled and prepared for the length and width as shown on the drawings. In case the surface on which apron is to be laid is below the low water level, the ground level may be raised upto low water level by dumping earth and the apron laid thereon. The quantity of stone required in the apron shall be re-worked out by taking the toe of pitching at higher level.

2503.3 Laying Wire Crates and Mattresses in the Apron

Wire crates shall be made from hot dipped galvanized mild steel wire of diameter not less than 4 mm in annealed condition having tensile strength of 300-450 MPa conforming to IS:280. The galvanizing coating shall be heavy coating for soft condition conforming to IS:4826.

The mesh of the crate shall not be more than 150 mm.

Wire crates for shallow or accessible situations shall be 3 metre x 1.5 metre x 1.25 metre in size. Where these have to be deposited and there is a change of overturning, the crate shall be divided into 1.5 metre compartments by cross netting.

For deep or inaccessible situations, wire crates can be made smaller subject to the approval of the Engineer.

Wire crates built in-situ, shall not be larger than 7.5 metres x 3 metres x 0.6 metre, nor smaller than 2 metres x 1 metre x 0.3 metre. Sides of large crates shall be securely stayed at intervals of not more than 1.50 metres to prevent bulging.

The netting shall be made by fixing a row of spikes on a beam at a spacing equal to the mesh. The beam must be a little longer than the width of netting required. The wire is to be cut to lengths about three times the length of the net required. Each piece shall be bent at the middle around one of the spikes and the weaving commenced from the corner.

A double twist shall be given at each intersection. The twisting shall be carefully done by means of a strong iron bar, five and half turns being given to the bar at each splice.

The bottom and two ends of the crate or mattress shall be made at one time. The other two sides shall be made separately and shall be secured to the bottom and the ends by twisting adjacent wires together. The top shall be made separately and shall be fixed in the same manner as the sides after the crates or mattress have been filled.

Wherever possible, crates shall be placed in position before filling with boulders. The crates shall be filled by carefully hand-packing the boulders as tightly as possible and not by merely throwing in stones or boulders.

For laying of wire crates in aprons of bridges, two situations arise :

i) Where the crates are to be laid in deep water and have to be dumped and then jointed together.

ii) Where depth of water is low or dry bed is available. In such cases, the crates can be laid at site.

2504 PITCHING / REVETMENT ON SLOPES

2504.1 Description

This work shall consist of covering the slopes of guide bunds, training works and road embankments with stone, boulders, cement concrete blocks or stones in wire crates over a layer of granular material called filter. While river side slopes are given this protection against river action, the rear slopes, not subjected to direct attack of the river, may be protected against ordinary wave splashing by 0.3-0.6 metre thick cover of clayey or silty earth and turfed.

2504.2 Pitching/Filter media

2504.2.1 Pitching : The pitching shall be provided as indicated in the drawings. The thickness and the shape of the stone pitching shall be shown on the drawing.

The stone shall be sound, hard, durable and fairly regular in shape. Quarry stone should be used. Round boulders shall not be allowed. The stones subject to marked deterioration by water or weather shall not be accepted.

The size and weight of stone shall conform to clause 5.3.5.1 of IRC:89. No stone, weighing less than 40 kg shall, however, be used. The sizes of spalls shall be a minimum of 25 mm and shall be suitable to fill the voids in the pitching.

Where the required size stones are not economically available, cement concrete blocks in M15 grade conforming to Section 1700 or stones in wire crates may be used in place of isolated stones of equivalent weight. Cement concrete blocks will be preferred wherever practicable. Use of geosynthetics has been dealt with in Section 700.

2504.2.2 Filter media : The material for the filter shall consist of sand, gravel, stone or coarse sand. To prevent escape of the embankment material through the voids of the stone pitching / cement concrete blocks as well as to allow free movement of water without creating any uplift head on the pitching, one or more layers of graded materials, commonly known as a filter medium, shall be provided underneath the pitching.

The gradation of the filter material shall satisfy the following requirements :

Provision of a suitably designed filter is necessary under the slope pitching to prevent the escape of underlying embankment material through the voids of stone pitching / cement concrete blocks when subjected to the attack of flowing water and wave action, etc. In order to achieve this requirement, the filter may be provided in one or more layers satisfying the following criteria :

$$\frac{\text{D 15 (Filter)}}{\text{D 85 (Base)}} < 5$$

$$4 < \frac{\text{D 15 (Filter)}}{\text{D 15 (Base)}} < 20$$

$$\frac{\text{D 50 (Filter)}}{\text{D 50 (Base)}} < 25$$

Notes :

1. Filter design may not be required if embankment consists of CH or Ch soils with liquid limit greater than 30, resistant to surface erosion. In this case, if a layer of material is used as bedding for pitching, it shall be well graded and its D 85 size shall be at least twice the maximum void size in pitching
2. In the foregoing, D 15 means the size of that sieve which allows 15 per cent by weight of the filter material to pass through it and similar is the meaning of D 30 and D 85.
3. If more than one filter layer is required, the same requirement as above shall be followed for each layer. The finer filter shall be considered as base material for selection of coarser filter.
4. The filter shall be compacted to a firm condition. The thickness of filter is generally of the order of 200 mm to 300 mm. Where filter is provided in two layers, thickness of each layer shall be 150 mm.

2504.3 Construction Operations

Before laying the pitching, the side of banks shall be trimmed to the required slope and profiles put up by means of line and pegs at intervals of 3 metres to ensure regular straight work and a uniform slope throughout. Depressions shall be filled and thoroughly compacted.

The filter granular material shall be laid over the prepared base and suitably compacted to the thickness specified on the drawings.

The lowest course of pitching shall be started from the toe wall and built up in courses upwards. The toe wall shall be in dry rubble masonry (uncoursed) conforming to Clause 1405.3, in case of dry rubble pitching and shall be in nominal mix cement concrete (M 15) conforming to Clause 1704.3 in case of cement concrete block pitching.

The stone pitching shall commence in a trench below the toe of the slope. Stone shall be placed by derrick or by hand to the required length, thickness and depth conforming to the drawings. Stones shall be set normal to the slope, and placed so that the largest dimension is perpendicular to the face of the slope, unless such dimension is greater than the specified thickness of pitching.

The largest stones shall be placed in the bottom courses and for use as headers for subsequent courses.

In hand placed pitching, the stone of flat stratified nature should be placed with the principal bedding plane normal to the slope. The pattern of laying shall be such that the joints are broken and voids are minimum by packing with spalls, wherever necessary, and the top surface is as smooth as possible.

When full depth of pitching can be formed with a single stone, the stones shall be laid breaking joints and all interstices between adjacent stones shall be filled in with spalls of the proper size and wedged in with hammers to ensure tight packing.

When two or more layers of stones must be laid to obtain the design thickness of pitching, dry masonry shall be used and stones shall be well bonded. To ensure regular and orderly disposition of the full intended quantity of stone as shown, template cross walls in dry masonry shall be built about a metre wide and to the full height of the specified thickness at suitable intervals and all along the length and width of the pitching. Within these walls the stones shall be hand packed as specified.

2504.4 Toe Protection

In conformity with clause 5.3.7. of IRC:89, a toe wall shall be provided at the junction of slope pitching and launching apron of a guide bund so as to protect the slope pitching

from falling even when the apron is not laid at low water level. The toe wall shall be in dry rubble masonry (uncoursed) conforming to Clause 1405.3 in case of dry rubble pitching or pitching/revetment with stones in wire crates and in nominal mix cement concrete (M 15) conforming to Clause 1704.3 in case cement concrete blocks have been used in pitching. For protection of ties of bank slopes terminating either in short aprons at bed levels or anchored in flooring / rocky bed, the provision of clause 8.2.2 of IRC:89 may be complied with. The relevant specifications of the protective works for individual components will be followed.

2505 RUBBLE STONE/CEMENT CONCRETE BLOCK FLOORING OVER CEMENT CONCRETE BEDDING

2505.1 This work shall consist of constructing rubble stone / c.c. block flooring laid over a cement concrete (M 15) bedding. The floor protection will comprise rigid flooring stated above with curtain walls and flexible apron.

2505.2 Construction Operations

Excavations for laying the bedding and floor protection works shall be carried out as per specifications under proper supervision. Before laying the foundation and protection walls, the excavated trenches shall be thoroughly inspected by the Engineer-in-Charge to ensure that :

a) There are no loose pockets and unfilled depressions left in the trench.

b) The soil at the founding level is properly compacted to true lines and level so as to have an even bedding.

c) All concrete and other elements are laid in dry bed.

Cement concrete nominal mix (grade M 15) of 300 mm thickness shall then be laid in accordance with provisions given in Section 1700 except that the surface of the concrete shall not be given a smooth finish. The paving work shall be embedded in green concrete.

Flooring shall consist of 150 mm thick flat stone/cement concrete block (nominal mix Grade M 15 conforming to Section 1700). It shall be bedded on a layer of cement mortar (1:3) prepared to Clause 1304. Spalls shall be used to fill in the voids. The joints shall then be filled with cement mortar and finished neat. The stone shall break joints and the joints shall not exceed 20 mm in thickness. Spacing of joints may be 20 m or so. The top of flooring shall be kept to 300 mm below the lowest bed level.

2506 DRY RUBBLE FLOORING

This work shall consist of constructing dry rubble flooring at cross drainage works for relatively less important works.

The base for the flooring shall be prepared to the specified levels and slopes and compacted suitably with hand rammers or other means to have an even bedding.

The thickness of flooring shall be made with one stone only. The stones shall then be laid closely on the prepared base in one or more layers as specified and the bond used shall be as specified by the Engineer.

2507 CURTAIN WALL AND FLEXIBLE APRON

2507.1 Curtain Wall

The rigid flooring shall be enclosed by certain walls (tied to the wing walls) with minimum depth below floor level of 2 m on upstream side and 2.5 m on downstream side. The curtain wall will be in cement concrete M 15/stone masonry in cement mortar 1:3. The rigid flooring shall be continued over the top width of curtain wall.

2507.2 Flexible Apron

Flexible apron 1 m thick comprising loose stone boulders (weighing not less than 40 kg) shall be provided beyond curtain walls for a minimum distance of 3 m on upstream side and 6 m on downstream side. The work of floor protection shall be simultaneously completed alongwith the work on bridge foundations.

2508 TESTS AND STANDARS OF ACCEPTANCE

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

2509 MEASUREMENTS FOR PAYMENT

The protection works shall be measured as set forth below. If directed by the Engineer for measurement, the materials may have to be stacked at site before laying and nothing extra will be paid to the Contractor for this stacking.

The earth work in construction of embankment for guide bund shall be measured in cubic metres unless otherwise specified.

The boulders/cement concrete blocks and wire crates in apron shall be measured in cubic metres.

The filter and stone pitching shall be measured separately in cubic metres unless otherwise specified.

Rubble stone/cement concrete blocks, flooring and cement concrete bedding shall be measured in cubic metres for each class of material.

Preparation of base for laying the flooring shall be deemed incidental to the work.

For laying apron, excavation upto an average depth of 150 mm shall be deemed to be included in the main item and shall not be measured separately unless otherwise specified. Excavation more than 150 mm shall be measured in cubic metres as given in Clause 304.

2510 RATE

The contract unit rate for the construction of embankment for guide bund shall cover the cost of all materials including transportation, laying, compacting, all labour, tools, equipment, sampling and testing, supervision and all incidentals necessary for completing the work according to these specifications.

The contract unit rate for one cubic metre of finished work of apron shall include the cost of all material, labour, tools and plant for completing the work according to above specifications. Excavation upto an average depth of 150 mm shall also be deemed to be included in the rate as dressing of the bed. Excavation this depth shall be paid for separately unless otherwise specified.

The contract unit rate for one cubic metre of filer or stone/cement concrete block pitching on slopes shall include the cost of preparing the bases, putting to the profiles, laying and compacting the filter and stone pitching of dry rubble/cement concrete block revetment for embankment slopes to the specified thickness, lines, curves, slopes and levels and all labour and materials as well as tools and plant required for the work.

The contract unit rate for rubble stone/cement concrete block flooring shall include the cost of all material, labour and tools and plant for completing the work as per these specifications.

2800

Repair of Structures

2801 DESCRIPTION

Repair of structures shall be carried out in accordance with the repair plans and these Specifications or as directed by the Engineer. Where repair work is not covered by these Specifications, special Specification may be framed.

Implementation of repair schemes shall also conform to provisions of IRC:SP:40.

2802 GENERAL

2802.1 Environmental Aspect

Care shall be taken to ensure suitable mitigation measures against noise and dust, pollution and damages to the environs whether temporary or permanent and shall be taken as incidental to work.

2802.2 Phasing

The sequence of work shall be in accordance with the drawings or as directed by the Engineer.

2802.3 Traffic Management

Traffic management, signage, signaling arrangement, barricading, and lighting arrangement shall be in accordance with Section 100 and with these Specifications and shall be considered as incidental to work.

2802.4 Safety Precautions

Adequate precautions shall be taken for safety of personnel, road users and existing services, during execution. These shall be considered as incidental to work.

Persons working shall wear safety helmets and rubber gloves.

2802.5 Dismantling and Removal of Material

Dismantling of any bridge component and removal of materials shall conform to Section 200 and this section and as shown on the drawings or as directed by the Engineer.

2803 SEALING OF CRACKS BY INJECTION OF EPOXY RESIN

2803.1 General

The work of epoxy adhesive utilizing the Structural Concrete Bonding Process shall conform to these Specifications.

2803.2 The Contractor shall furnish detailed methodology of construction including sources of supply of material, tools, equipment and appliances to be used on work, details of personnel and supervision.

2803.3 Personnel

The Contractor's personnel shall be qualified and experienced in epoxy injection process.

2803.4 Material

The material for injection shall be suitable two-component low viscosity epoxy resin, having the required characteristics of bonding with concrete and resistance to moisture penetration. Epoxy mortar or polysulphide resin may be used for sealing the surface.

The material for epoxy injection shall conform to the following :

i) The mixing ratio of resin and hardener shall generally be between 1 to 1 and 2 to 1 by volume subject to manufacturer's recommendation.

ii) Neither the mixed epoxy adhesives nor their individual component shall contain solvents and thickners.

iii) The components shall be free of lumps or foreign material. The viscosity of the individual components shall not change more than $\pm$ 15 percent when kept in closed containers at 25°C after two weeks.

iv) Consistency requirement

		Standard Version cps	**Low Viscosity Version cps**
	Viscosity of Mixed Adhesive at 25°C	(200-300)	(100-190)
v)	Pot Life of mixed adhesive at 25°C	1 hour $\pm$15 minutes *	
vi)	Set time of mixed adhesive at 25°C	3 - 6 hours	

* In the case of two component injection system where resin and hardener get mixed at point of injection pot life at 25°C shall be not greater than 15 min $\pm$ 10 minutes.

2803.5 Equipment for Injection

The equipment shall be portable, positive displacement type pumps with interlock to provide positive ratio control of exact proportions of the two components at nozzle. The pumps shall be generally electrically powered and shall provide in-time metering and mixing. The tolerance on mix ratio shall be 5 percent by volume. The injection equipment shall have automatic pressure control capable of discharging mixed adhesive at any pre-set pressure within the prescribed limits and shall be additionally equipped with a manual pressure control.

The injection equipment shall be equipped with sensors on both the components A and B reservoirs that will automatically stop the machine when only one component is being pumped to the mixing head.

If considered appropriate, suitable compressed air operated epoxy injection gun can be used with prior approval of the Engineer for manual injection of mix when resin and hardener had been mixed in a separate unit.

2803.6 Preparation

Surfaces adjacent to cracks or other areas of application shall be cleaned of dirt, dust, grease, oil efflorescence or other foreign matter by brushing/water jetting/sand blasting. Acids and corrosives shall not be permitted for cleaning.

Entry ports shall be provided along the crack at intervals of not more than the thickness of concrete at the location.

Surface seal material shall be applied to the face of the crack between the entry ports. For through cracks, surface seal shall be applied to both faces.

Before proceeding with the injection, the surface seal material must gain adequate strength with respect to concrete strength of the member/injection pressure.

2803.7 Epoxy Injection

Injection of epoxy adhesive shall begin at lowest entry port and continue until there is an appearance of epoxy adhesive at the next entry port adjacent to the entry port being pumped.

When epoxy adhesive travel is indicated by appearance at the next adjacent port, injection shall be discontinued on the entry port being pumped and entry port shall be sealed. Thereafter, epoxy injection shall be transferred to next adjacent port where epoxy adhesive has appeared.

Epoxy adhesive injection shall be performed continuously until cracks are completely filled.

If port to port travel of epoxy adhesive is not indicated, the work shall immediately be stopped. In case the volume of the injected material exceeds 2 litres for a particular entry port, the work shall be stopped and the specifications may be reviewed.

2803.8 Precautions for Application

a) Unless otherwise specified, components A and B, i.e., resin and hardener, shall be at a temperature between 10°C and 35°C at the time of mixing.

b) Temperature of structural member during epoxy injection shall be between 10°C and 35°C unless otherwise specified.

c) Immediately prior to use, each component shall be thoroughly mixed with a clean paddle. The paddle shall be of a type that does not induce air into the material. Separate clean paddle must be used for each component.

d) Any heating of the adhesive components shall be done by application of indirect heat in case the work is to be done in cold climate.

e) Just before use, the two components shall be thoroughly mixed in the ratios specified by the manufacturer. The length of mixing time shall be in strict accordance with manufacturer's recommendations. When mixed, all adhesives with different coloured components shall have a uniform colour without streaks.

f) The use of solvents and thinners will not be permitted except for cleaning of equipment.

2803.9 Testing

2803.9.1 Material Testing : Prior to approval of the material, the following tests shall be carried out at site or in an authorized laboratory for each batch of resin and hardener and each combination thereof at the cost of the Contractor.

i) Viscosity test for resin and hardener and the mix – three specimens each.

ii) Pot life test - three specimens each.

iii) Bond test – three specimens each.

iv) Shear test – six specimens each, 3 after 24 hours and the other three after 72 hours of curing.

Subsequent tests shall be carried out as directed by the Engineer.

a) Pot Life Tests

i) 500 gm of resin formulation shall be prepared by thoroughly mixing the resin and hardener/accelerator/catalyst component in proposed proportion in a 1 kg capacity hemispheral porcelain bowl by means of a spatula or any other agitating device and note down the time and the ambient temperature.

ii) With a clean dry 25 mm size painter’s brush, the resin formulation shall be applied on a clean dry surface such as cement concrete over 15-20 cm length, starting immediately after mixing the formulation and repeating operation every five minutes. When it becomes just difficult to spread the resin properly with the brush, the time is noted. The time elapsed since completion of mixing of resin formulation is taken as its pot life.

iii) One pot life test shall be performed on commencement of work and the same shall be repeated every four hours.

iv) In case the material fails to satisfy the pot life test it shall not be used for injection.

Where the resin and hardener get mixed at point of injection, the pot life is not important and no tests may be required.

b) Bond Test

A standard 150 mm diameter and 300 mm long concrete cylinder shall be cast in 2 pieces by providing a separating media at an axis of 45°C to the longer axis of the cylinder (refer to Fig. 2800/1).

Three sets of such split cylinders shall be prepared in advance. Two pieces of each set shall be joined with epoxy mortar at four points to give a clear gap of about 0.2 mm, which will be injected with epoxy resin at site. After epoxy has been cured, load test is carried out on the cylinder which shall not be less than 80 per cent of the cube strength of the concrete mix and the failure shall not take place at the joint injected with epoxy resin.

c) Shear Tests

Two steel plates, minimum 3 mm thick, shall be bonded with epoxy at site using the same resin mix as used/proposed to

be used for injection. The assembly shall be kept in mechanical clamp till epoxy is cured. A total of six specimens shall be prepared for each batch of materials. Three test specimens shall then be subjected to a shear force along the axis after 24 hours and the minimum shear strength before failure shall not be less than 1 MPa. (refer Fig. 2800/2).

The remaining test specimens shall be similarly tested after 72 hours of curing. The shear strength before failure shall not be less than 2.5 MPa.

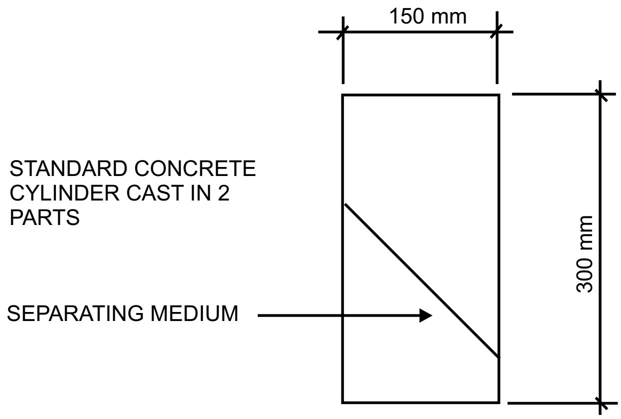

Fig. 2800/1

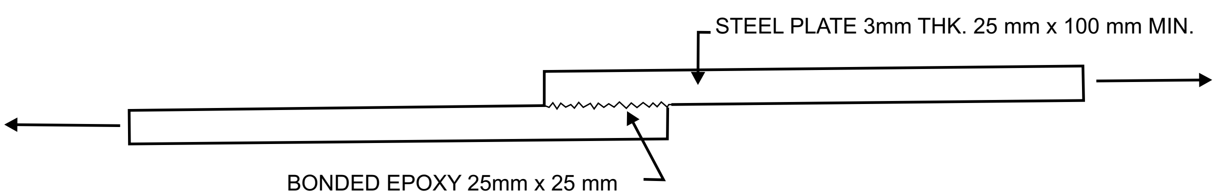

Fig. 2800/2

2803.9.2 Core test : If directed by the Engineer, core tests shall be conducted for the acceptance of the work. The selection of the location of cores shall be made under the direction of the Engineer in such a way that damage in critical/stressed areas of the structure is avoided. The procedure for the test shall be as under.

The Contractor shall obtain 5 cm diameter initial core samples in the first 50 linear metres. Thereafter, frequency of core sampling shall be as specified or as agreed by the Engineer.

The depth of the core shall generally be less than 20 cm.

Tests and Acceptance Criteria shall be as follows :

a) Penetration/Visual Examination – a minimum of 90 percent of the crack shall be full of epoxy adhesive.

b) Bond Strength : Concrete failure before adhesive failure or 40 MPa with no failure of either concrete or adhesive.

If the cores taken in first 50 m length pass tests as specified above, epoxy adhesive injection work at area represented by cores will be accepted.

If cores fail either by lack of penetration or bond strength, work shall not proceed further until the areas represented by the cores are re-injected and retested for acceptance.

Filling of Field Control Testing Core Holes

This procedure consists of using two-component bonding agent applied to surfaces of cored holes followed by application of Non-Shrink cement grout mix placed by hand trowel, thoroughly rodded and tamped in place, and finished to match finish and texture of existing concrete to the satisfaction of the Engineer. Materials and procedures for filling testing core holes shall be submitted to and approved by the Engineer before proceeding with core testing work.

2803.9.3 Test for injection equipment : At all times during the course of the work the Contractor shall keep complete and accurate records and make available to the Engineer of the pressure and ratio tests specified above so that the efficacy and accuracy of the injection equipment is verified.

In addition, the Engineer at any time without prior intimation of the Contractor may request the Contractor to conduct the tests specified below, in the presence of the Engineer.

a) **Pressure Test**

The mixing head of the injection equipment shall be disconnected and the two adhesive component delivery lines shall be attached to the pressure check device, which shall consist of two independent valved nozzles capable of sensing the pressure. The check device shall be closed and equipment operated until the gauge pressure in each line reads 5 MPa. The pumps shall be stopped and the gauge pressure shall not drop below 4 MPa within 2 minutes.

The pressure test shall be run for each injection unit at the beginning and after break of every shift.

b) **Ratio Test**

The mixing head of the injection equipment shall be disconnected and the two adhesive components shall be pumped simultaneously through the ratio check device, which shall consist of two independent valved nozzles. There shall be a pressure gauge capable of controlling back pressure by opening or closing valved nozzles capable of sensing the back pressure behind each valve. The discharge pressure shall be adjusted to read 5 bar for both adhesive components, which shall be simultaneously discharged into separate calibrated containers during the same time period and the amounts discharged into the calibrated containers simultaneously during the same period shall be compared to determine that the volume/ discharge conforms to the manufacturer's recommended ratio for applicable material.

2804 EPOXY MORTAR FOR REPLACEMENT OF SPALLED CONCRETE

2804.1 Material

The epoxy resins for use in the mortar shall be obtained from a reputed manufacturer and the mortar shall be prepared in conformity with the manufacturer's recommendations.

They shall generally conform to the following :

Pot Life	:	90 minutes at 25°C 60 minutes at 30°C 45 minutes at 35°C
Bond Strength	:	12 MPa
Tensile Strength	:	16 MPa

The Contractor shall carry out tests on the samples made and meet requirements indicated above.

The sand content in the mortar shall be in accordance with the desired consistency.

2804.2 Proportioning and Mixing

The resin and hardener shall be mixed before adding the dry filler. The mixed ready to use mortar should not contain lumps of unwetted filler and should be uniform in colour. For a total weight of 1 kg or less, hand mixing will be sufficient. For quantities in excess of 1 kg, the component shall be mixed for 3 minutes with a slow speed 400-600 rpm electric drill

with a Jiffy mixer. The stirrer shall be moved up and down and along the sides until an even streak free colour is obtained. Whipping in an excessive amount of air shall be avoided. If no power is available, a flat putty knife may be used to reach into the corners of the can and hand mixing done for at least 5 minutes.

2804.3 Surface Preparation

Surface upon which epoxy is to be placed shall be free of rust, grease, oil, paint, asphalt, loose material, unsound concrete, dust or any other deleterious material.

Since cured epoxy does not provide adequate bond with any material, all overlay, whether epoxy or cement based, shall be done within pot life of the base epoxy layer.

2804.4 Contaminants, such as oil, grease, tar, asphalt, paint, wax, curing compounds or surface impregnants like linseed oil or silicons, including laitance and weak or loose concrete shall be removed. When bonding to asphalt, the surface should be roughened so that clean aggregate is exposed. Epoxy bonding agents shall not be applied when it rains, or in standing water. The surface must be dry.

Two general methods of surface preparation shall be followed :

a) Mechanical that includes grinding, grit blasting, water blasting and scarification.

b) Chemical that includes acid etching with 15 per cent by weight of hydrochloric solution, followed by repeated flushing with high pressure stream of water.

2804.5 Application

Epoxy primer coat shall be applied with the help of stiff nylon bristle brushes or hard rubber rollers or spray gun depending upon the nature of surface and extent of work area. As far as possible, the coating shall be uniformly thick.

Before the primer coat is fully cured, epoxy mortar shall be applied by means of trowels and floats. The interval between the application of primer coat and epoxy mortar shall be approximately 15/30 minutes depending upon the ambient temperature.

Seal Coat shall be applied after 24 hours curing, after mild roughening of the surface of the mortar.

2804.6 Coverage

The coverage of resin mix would depend on the system of resin used. However, as a general guideline the coverage area shall be as under :

a) Primer Coat. One kg of resin-hardener mix covers an area of 3-6 square metres per coat depending on the finish of the concrete.

b) Epoxy Mortar. One square metre of surface requires approximately 20-24 kg of epoxy mortar when laid to a thickness of 10 mm.

c) Seal Coat. 4 to 6 square metres per kg of mix depending on the temperature of application.

2804.7 Cleaning and Maintenance of Equipment

Tools and equipment are best cleaned immediately after use since the removal of cured resin is difficult and time consuming. The bulk of resin shall be removed using a scraper and remainder washed away completely using solvents such as toluene, xylene or acetone. Equipments used for epoxy shall always be cleaned before it hardens. Solvents used for this purpose may be Acetone (flammable), Methyl Ethyl Kethone (flammable), Methyl Chloride (non-flammable). Cured epoxies may be removed using Methylene Chloride.

2804.8 Testing

Epoxy used for making mortar shall conform to all requirements and testing procedures as laid down in Clause 2803.9.

2804.9 Handling Precautions

Epoxy resins can cause irritation of skin in sensitive persons if incorrectly handled. The resin and hardener should not be allowed to come into direct contact with skin. The most effective protection is achieved by wearing rubber or polythene gloves.

2804.10 Personnel and Environment Safety

Any skin contact with epoxy materials, solvents and epoxy strippers should be avoided. Epoxy resins and particularly epoxy hardeners (B component) may cause a rash on the skin. The official toxicity classification on the container labels may be looked for before starting work.

Rubber gloves, with a cloth liner, and protective clothing shall be worn. Barrier creams are recommended but are not substitutes for protective clothing. Eyes shall be protected where splashing could occur while spraying or mixing. Good ventilation shall be ensured

and inhalation of vapours avoided. If materials are sprayed, a respirator shall be used.

If skin contact occurs, it shall be immediately washed with a cleaner, followed by soap and water. Should eye contact occur, it shall be flushed immediately with plenty of water for 15 minutes and a doctor called for.

If contact occurs with the clothing, it shall be immediately changed to prevent further skin contact, and if the contact occurs with components A or B, the clothing shall be thrown away. Hardened epoxy is not harmful but will break the clothing.

All emptied, used buckets, rags and containers shall be removed from site. These shall be stored in waste disposal bags and suitably disposed.

2805 EPOXY BONDING OF NEW CONCRETE TO OLD CONCRETE

2805.1 Epoxy resin used for bonding shall be obtained from a reputed manufacturer. The pot life of such bonding epoxy shall not be less than 60-90 minutes at normal temperature.

2805.2 The entire surface of the existing concrete member should be thoroughly cleaned by wire brush and then with compressed air to remove dust and loose particles from the surface. Any crack or spalling of concrete shall be sealed by epoxy injection/ epoxy mortar/grouting as decided by the Engineer. A coating of suitable epoxy resin at the rate of 0.8 kg/sq.m (minimum) should then be applied on the surface of the existing concrete members. Fresh concrete shall then be placed within the pot life of the resin system.

2805.3 Testing

2805.3.1 Epoxy used for bonding work shall satisfy the criteria mentioned in Clause 2803.9.

2805.3.2 Two concrete cubes 150 mm size cast as per approved design mix shall be placed, as shown in Fig. 2800/3 at a distance of 150 mm from each other. Epoxy resin system suggested for bonding new to old concrete shall be applied on the opposite faces of the cubes.

Fresh cement concrete cube of grade as per approved design mix shall be cast with water cement ratio of 0.4 or less in the manner shown in Fig. 2800/3. The assembly shall be cured in water for 28 days and steel spacer removed thereafter.

The cube assembly shall be subjected to compression load after 28 days of curing, thereby subjecting the bond to shearing load. Failure must not occur at this joint.

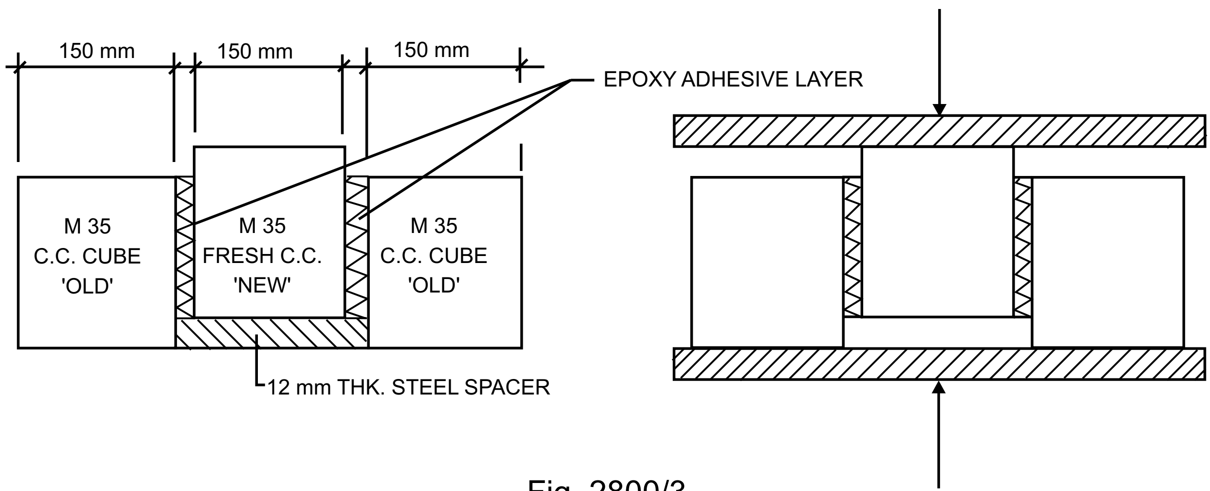

Fig. 2800/3

2806 CEMENT GROUTING

2806.1 Material

Grouting shall normally be performed with a mixture of neat Portland Cement and water. Other additives and admixtures may be added to improve the impermeability, strength, etc. on the approval of the Engineer. The size of the particles and the consistency of the grout must be suited to the passageways it must follow. Neat grout will not flow freely into holes smaller than about three times the largest cement particle. Except in large cavities where thick mortar can be placed, the sand should all pass the 28-mesh sieve and have a large portion passing the 50 and the 100 mesh sieves. The proportions of Ordinary Portland Cement to sand will depend upon the size of the spaces to be filled and will vary from a neat grout to about 1:1 mix. The amount of water to be added depends upon the consistency required. Grouts with as little as 16 litres of water per bag of cement could be handled and it should seldom be necessary to use more than 35 to 40 litres of water per bag of cement.

Where necessary and approved by the Engineer, admixtures to Portland Cement grout mixtures may be added for delaying the setting time, increasing flow ability, minimizing segregation and shrinkage.

2806.2 Preparation

The surface shall be cleaned with wire brush and compressed air, 15 m dia and 150 to 200 mm deep holes along the length of the cracks at a spacing of 500 mm may be drilled by wet drilling using rotary percussion drills and nipples inserted in these holes.

2806.3 Proportioning, Mixing and Equipment for Grouting

The cement grout shall be mechanically mixed using a system of power-driven paddles of high speed centrifugal pump. The grout pump to be used shall permit close control of pressures to allow a flexible rate of injection with minimum clogging of valves and ports. The most satisfactory equipment for injecting grout is a pump of the double-acting flexible reciprocating type giving a steady flow. The grout pump shall be so placed as to reduce the waste in cleaning lines. It is preferable to add 50 percent or more of the mixing water into the mixer before adding the dry ingredients and then the remaining water. A continuous supply of grout is preferable to an intermittent one. Consistency of the grout may be determined by trials starting with thin grout i.e. about 40 litres of water per bag of cement and progressively decreasing the water content to about 15 litres per bag of cement.

Where the mixer and pump are combined in one unit, the dry material shall be screened before mixing. If the mixer and pump are in separate units, the grout shall pass through a screen before it enters the pump.

2806.4 Application

Highest practical pressure within the limits 100-400 kPa should be used in order to force the surplus water from the grout. As the pressure may be distributed hydraulically over considerable areas, vigilance must be exercised to prevent damage or needless waste of grout. Grouting is to be done by attaching a packer (consisting of expansible tube of rubber) to the end of the grout supply pump through the holes and nipples.

Pressure shall be steady to ensure a continuous flow of grout. Grouting shall not be continued till the hole consumes mix at the rate of not less than 30 litres in 20 minutes or until refusal at the grouting pressure of 400 kPa at any hole until refusal. Should the grout escape from an adjacent nipple, it should be plugged or capped. Any seam, crack or joint through which grout escapes shall be caulked with epoxy mortar as soon as thick grout appears.

2806.5 Cleaning of Equipment

After completion of each grouting operation or temporary shutdown, it is advisable to force clear water through the pump until the discharge line shows no colour, after which the pump covers shall be removed and the valve chambers thoroughly cleaned.

2806.6 Testing

Percolation test done at the end of grouting operation shall give a value of less than 2 lugions.

NOTE : For specialised treatment like polymer modified cementitious grout injection, manufacturer's literature and specifications shall be followed.

2807 GUNITING/SHOTCRETE

2807.1 The gunite is a mixture of cement, sand and water. It comprises 100 parts by weight of cement, 300 parts by weight quartz sand, 35-50 parts by weight water and 2 parts by weight approved quick setting compound. In general, dry mix shotcrete shall be used.

2807.2 Ordinary Portland cement conforming to IS:269 shall be used in guniting.

2807.3 Sand for guniting shall comply with the requirements stipulated in IS:383. In general, sand should neither be too coarse to increase the rebound nor too fine to increase the slump. Sand should preferably have a moisture content between 3 to 6 percent.

The grading of sand shall lie within the limits given below :

IS Sieve Designation	Percent Passing the Sieve
4.75 mm	95 – 100
2.36 mm	65 – 90
1.18 mm	45 – 75
600 micron	30 – 50
300 micron	10 – 22
150 micron	2 -8

2807.4 For thick sections it may be advantageous to incorporate coarse aggregate in the mix provided adequate guniting equipment is available. Coarse aggregate, when used, shall conform to grading given in Table I of IS:9012. The percentage of coarse aggregate may normally be kept as 20 to 40 percent of the total aggregate and the mix shall be suitably designed

2807.5 Water/cement ratio for guniting shall fall within the range 0.35 to 0.50 by mass, wet enough to reduce the rebound. Drying shrinkage may be between 0.06 percent to 0.10 percent. The quick setting compound shall be added at the nozzle with water just before guniting.

2807.6 Workmanship

The cement and sand shall be batched and mixed and conveyed through a hose pipe with the help of compressed air. A separate line shall bring the water under pressure. The

cement, sand and water mix shall be passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired. The density of gunite shall not be less than 2000 kg/cu.m. The strength of gunite shall not be less than 25 MPa. For effective guniting, the nozzle shall be kept 60 to 150 cm away from the surface, preferably normal to that surface. While enclosing reinforcement bars during repairs, the nozzle shall be held closer at a slight angle and the mix shall be wetter than the normal.

2807.7 Test panels simulating actual field conditions shall be fabricated for conducting preconstruction testing. The procedure for testing the cubes or cylinders taken from the panels stipulated in clause 6 of IS:9012 shall be followed.

2807.8 It should be ensured from tests that a strength of about 25 MPa at 28 days is available for the mortar/concrete mix.

2807.9 The defective concrete shall be cut out to the full depth till sound concrete surface is reached. Under no circumstances should the thickness of concrete to be removed be less than clear cover to the main reinforcement. No square shoulders shall be left at the perimeter of the cut-off portion and all edges shall be tapered. Thereafter, all loose and foreign materials should be removed and the surface be sandblasted to make it rough to receive shotcrete after applying a coat of bonding epoxy as per recommendation of the manufacturer @ 1.0 kg per 1.5 sq.m of surface area.

2807.10 The exposed reinforcement shall be thoroughly cleaned free of rust, scales etc. by wire brushing. Wherever the reinforcements have been corroded, the same shall be removed and replaced by additional reinforcement. Before application of gunite, a coat of neat cement slurry should be applied on the surface of the reinforcement.

2807.11 Sufficient clearance shall be provided around the reinforcement to permit encashment with sound gunite. Care shall be taken to avoid sand pockets behind the reinforcement.

2807.12 A thickness of 25 to 40 mm of gunite can normally be deposited in one operation. If, for some reason, the total thickness is to be built up in successive operations, the previous layer should be allowed to set but not become hard before the application of the subsequent layer. It would always be necessary to apply guniting on a damp concrete surface.

2807.13 Where required, welded wire fabrics 5 cm x 5 cm x No. 10 gauge shall be provided in the first layer of guniting. The fabric shall be tied properly. In case the damage to the concrete member is too deep, the specifications for guniting as well as requirement of placement of wire mesh has to be decided as per field conditions.

2807.14 The stipulations given in IS:9012 regarding application of gunite should be followed so as to keep the rebound to the minimum. The quality of guniting and workmanship shall be such that the percentage of rebound mentioned in IS:9012 can be adhered to. In no circumstances shall the rebound material be re-used in the work.

2807.15 It would be desirable that green gunite is moistened for at least 7 days. Guniting work shall not be done during windy or rainy conditions.

2808 REPLACEMENT/RECTIFICATION OF BEARINGS

2808.1 The replacement/rectification of bearings shall be carried out in accordance with approved repair plan or as approved by the Engineer.

2808.2 Lifting of superstructure spans may be carried out by jacking up from below or by lifting the span from top. Where jacks are employed, their location/number and size shall be selected in such a manner so that there are no undue stresses created in the structure. Jacks may be placed on piers/pier caps or specially erected trestles in accordance with the approved methodology for lifting of superstructure. All jacks shall be operated from one control panel by a single control lever. The system will have provision for manual over ride to control the loads of any particular jack. The jacks should be so synchronized that differential lift between individual jacks shall not exceed 1 mm.

2808.3 Necessary repair/replacement of bearings shall be carried out as indicated in the repair plan or as directed by the Engineer. Care shall be taken to plan the execution of repair in the shortest possible period.

2808.4 Precautions during Lifting of Girders for Rectification of Bearings.

Walkie talkies system or similar audio arrangements should be available for communicating instructions regarding lifting, stopping, starting etc. The operator shall have a clear view of the jacks and the lifting of each girder controlled by reading the dial gauges.

2809 DISMANTLING OF CONCRETE WEARING COAT

2809.1 Commencement of Dismantling

i) Before commencing dismantling, the nature and condition of concrete, the condition and position of reinforcement should be ascertained. The Contractor shall familiarize himself with the structural design and ensure that the overall stability of the bridge is not affected.

ii) The existing expansion joint assemblies shall be removed carefully along the entire width of the carriageway. The deck slab for a width

of 400 mm on either side should be removed for placing of reinforcement, anchor rods, anchor bolts and other fixing assemblies for the new expansion joints and pouring of fresh concrete. The gap between the girders over the piers should be cleared of all debris. A temporary platform in the gap at the end of girders shall be erected to collect the materials falling down during concreting and fixing of expansion joints.

iii) The service lines, if any, shall be disconnected/diverted before the dismantling work starts.

2809.2 Dismantling of concrete wearing coat shall be carried out using jack hammers or suitable manual methods as approved by the Engineer. Care should be taken to avoid any damage to the existing structure including reinforcement or prestressing anchorages for cables, if any, located in the deck slab.

2809.3 Precautions during Dismantling Work

For general guidelines, reference may be made to Section 100.

Dismantling work shall not be carried out at night, or during storm or heavy rain. A warning device shall be installed in the area to be used to warn the workers in case of mishap/ emergency.

Safety helmets conforming to IS:2925 shall be used by the workmen engaged in dismantling work. The sheds and tool boxes should be located away from the work site. Goggles preferably made up of celluloids and gas masks shall be worn at the time of dismantling, especially where tools like jack hammers are deployed to protect eyes from injuries from flying pieces, dirt, dust etc. Leather or rubber gloves shall be worn by the workers during the demolition of RCC work. Screens made of GI sheets shall be placed wherever necessary to prevent the flying pieces from injuring the workers.

Water should be sprayed to reduce the dust while removing concrete wearing course with jack hammer. No work shall be taken up under the span when dismantling work is in progress.

2810 EXTERNAL PRESTRESSING

2810.1 Various components constituting the system of external prestressing are as follows :

H.T. Strands/Wires, HDPE Sheathing, Deviator Blocks, Anchor Plates, Anchorages and grouting material.

2810.2 Material

H.T. Strands/Wires : H.T. Strands wires shall conform to Section 1000.

HDPE Sheathing : HDPE Sheathing shall conform to IS:4984 suitable for a working pressure of 6 bars. Its density shall be 955 kg/cu.m, shore hardness D63, yield stress 24 MPa and ultimate tensile strength 35 MPa.

Deviator Blocks : As necessitated by the profile of the external cable, suitable strand/ wire deviator block fabricated from M.S. Sections shall be provided. The deviator block shall be given a coat of suitable paint (preferably epoxy based) after sand blasting.

Anchorages : Depending upon the prestressing force, suitable anchorages and wedges shall be used conforming to relevant codes and section 1800.

2810.3 Workmanship

a) Stressing of cables shall be carried out as per instructions given in the drawings, and conforming to Section 1800.

b) Care should be taken to avoid any damage to the existing structure by way of stress concentration or any other reason during fixing of the deviator blocks and after stressing of cable. The deviator blocks shall be so fixed as not to allow any movement due to prestressing forces. Radius of curvature of the surface of the deviator block interfacing with the cable shall be minimum one metre.

c) The anchorages shall be sealed with suitable epoxy mortar system after the stressing of cables. A minimum cover of 50 mm shall be provided for the anchor plates and anchorages.

d) Suitable grouting inlet points and vent points shall be provided by way of HDPE “T” vent connections to the sheathing.

e) Grouting of cables shall be carried out as per provisions made in Section 1800.

2810.4 It shall be ensured that no part of the existing structure is damaged/distressed due to the external prestressing.

The behaviour of the girder shall be monitored by measurement of deflection so that only required amount of external prestressing is imparted to the girder. Care shall be taken to avoid excess prestressing and impairment to the girders.

2811 TESTS AND STANDARS OF ACCEPTANCE

The materials shall be tested in accordance with these Specifications and shall meet the prescribed criteria.

The work shall conform to these Specifications and shall meet the prescribed standards of acceptance.

2812 MEASUREMENTS FOR PAYMENT

a) Measurement for sealing of cracks and injection shall be made by weight of epoxy consumed in kg for epoxy grouting. For provision of nipples required for grouting, the payment shall be for number of nipples inserted.

b) Measurement for sealing of cracks and injection shall be made by weight of cement consumed in kg for cement grouting.

c) Measurement for application of epoxy mortar for specified thickness shall be per square metre of surface area of application.

d) Measurement for bonding of old and new concrete by epoxy mortar shall be measured in square metre surface area of interface.

e) Measurement for guniting/shotcreting, shall be per square metre of surface area of application.

f) Payment for replacement/rectification of bearings shall be for each number of bearing assembly replaced/rectified.

g) Dismantling of wearing coat shall be measured in square metre of area of wearing course dismantled.

h) Provision of external prestressing shall be measured in tonnes of H.T. steel strand/wire measured from anchorage to anchorage before stressing.

2813 RATE

The contract unit rate for sealing of cracks and injection of cement grout shall include cost of all materials, labour, tools and plant, placing in position, testing, curing and other incidental expenses for the satisfactory completion of the work as per these Specifications.

The contract unit rate for application of epoxy mortar for specified thickness shall include cost of all materials, labour, tools and plant, placing in position, testing and other incidental

expenses including surface preparation for the satisfactory completion of the work as per these Specifications and as shown on the drawings.

The contract unit rate for guniting/shotcreting shall include cost of all materials, labour, tools and plant, placing in position, testing, curing, surface preparation and other incidental expenses including the provision of nipples for the satisfactory completion of the work as per these Specifications.

The contract unit rate for replacement/rectification of bearings shall include cost of all materials, labour, tools and plant, placing in position, site welding/riveting/bolt connections, operation of jacks and other incidental expenses for the satisfactory completion of the work as per these Specifications and as shown on the drawings.

The contract unit rate for dismantling of wearing coat shall include cost of all materials, labour, tools and plant, traffic management, signages, safety precautions and other incidental expenses including removal of existing expansion joints for the satisfactory completion of the work as per these Specifications.

The contract unit rate for external prestressing shall include cost of all materials, labour, tools and plant, temporary works, testing, curing and other incidental expenses including the careful monitoring of the deflection of girders being externally prestressed for the satisfactory completion of the work as per these Specifications and as shown on the drawings.

2900

Pipe Culverts

2901 SCOPE

This work shall consist of furnishing and installing reinforced cement concrete pipes, of the type, diameter and length required at the locations shown on the drawings or as ordered by the Engineer and in accordance with the requirements of these Specifications.

2902 MATERIALS

All materials used in the construction of pipe culverts shall conform to the requirements of Section 1000.

Each consignment of cement concrete pipes shall be inspected, tested, if necessary, and approved by the Engineer either at the place of manufacture or at the site before their incorporation in the works.

2903 EXCAVATION FOR PIPE

The foundation bed for pipe culverts shall be excavated true to the lines and grades shown on the drawings or as directed by the Engineer. The pipes shall be placed in shallow excavation of the natural ground or in open trenches cut in existing embankments, taken down to levels as shown on the drawings. In case of high embankments where the height of fill is more than three times the external diameter of the pipe, the embankment shall first be built to an elevation above the top of the pipe equal to the external diameter of the pipe, and to width on each side of the pipe of not less than five times the diameter of pipe, after which a trench shall be excavated and the pipe shall be laid.

Where trenching is involved, its width on either side of the pipe shall be a minimum of 150 mm or one-fourth of the diameter of the pipe whichever is more and shall not be more than one-third the diameter of the pipe. The sides of the trench shall be as nearly vertical as possible.

The pipe shall be placed where the ground for the foundation is reasonably firm. Installation of pipes under existing bridges or culverts shall be avoided as far as possible. When during excavation the material encountered is soft, spongy or other unstable soil, and unless other special construction methods are called for on the drawings or in special provisions, such unsuitable material shall be removed to such depth, width and length as directed by the Engineer. The excavation shall then be backfilled with approved granular material which shall be properly shaped and thoroughly compacted upto the specified level.

Where bed-rock or boulder strata are encountered, excavation shall be taken down to atleast 200 mm below the bottom level of the pipe with prior permission of the Engineer and all rock/boulders in this area be removed and the space filled with approved earth,

free from stone or fragmented material, shaped to the requirements and thoroughly compacted to provide adequate support for the pipe.

Trenches shall be kept free from water until the pipes are installed and the joints have hardened.

2904 BEDDING FOR PIPE

The bedding surface shall provide a firm foundation of uniform density throughout the length of the culvert, shall conform to the specified levels and grade, and shall be of one of the following two types as specified on the drawings :

i) **First Class bedding :** Under first class bedding, the pipe shall be evenly bedded on a continuous layer of well compacted approved granular material, shaped concentrically to fit the lower part of the pipe exterior for atleast ten per cent of its overall height or as otherwise shown on the drawings. The bedding material shall be well graded sand or another granular material passing 5.6 mm sieve suitably compacted/rammed. The compacted thickness of the bedding layer shall be as shown on the drawings and in no case shall it be less than 75 mm.

ii) **Concrete cradle bedding :** When indicated on the drawings or directed by the Engineer, the pipe shall be bedded in a cradle constructed of concrete having a mix not leaner than M 15 conforming to Section 1700. The shape and dimensions of the cradle shall be as indicated on the drawings. The pipes shall be laid on the concrete bedding before the concrete has set.

2905 LAYING OF PIPE

No pipe shall be laid in position until the foundation has been approved by the Engineer. Where two or more pipes are to be laid adjacent to each other, they shall be separated by a distance equal to at least half the diameter of the pipe subject to a minimum of 450 mm.

The arrangement for lifting, loading and unloading concrete pipes from factory/yard and at site shall be such that the pipes do not suffer any undue structural strain, any damage due to fall or impact. The arrangement may be got approved by the Engineer.

Similarly, the arrangement for lowering the pipe in the bed shall be got approved by the Engineer. It may be with tripod-pulley arrangement or simply by manual labour in a manner that the pipe is placed in the proper position without damage.

The laying of pipes on the prepared foundation shall start from the outlet and proceed towards the inlet and be completed to the specified lines and grades. In case of use of pipes with bell-mouth, the belled end shall face upstream. The pipes shall be fitted and matched so that when laid in work, they form a culvert with a smooth uniform invert.

Any pipe found defective or damaged during laying shall be removed at the cost of the Contractor.

2906 JOINTING

The pipes shall be jointed either by collar joint or by flush joint. In the former case, the collars shall be of RCC 150 to 200 mm wide and having the same strength as the pipes to be jointed. Caulking space shall be between 13 and 20 mm according to the diameter of the pipe. Caulking material shall be slightly wet mix of cement and sand in the ratio of 1:2 rammed with caulking irons. Before caulking, the collar shall be so placed that its center coincides with the joint and an even annular space is left between the collar and the pipe.

Flush joint may be internal flush joint or external flush joint. In either case, the ends of the pipes shall be specially shaped to form a self centering joint with a jointing space 13 mm wide. The jointing space shall be filled with cement mortar, 1 cement to 2 sand, mixed sufficiently dry to remain in position when forced with a trowel or rammer. Care shall be taken to fill all voids and excess mortar shall be removed.

For jointing pipe lines under light hydraulic pressure, the recess at the end of the pipe shall be filled with jute braiding dipped in hot bitumen or other suitable approved compound. Pipes shall be so jointed that the bitumen ring of one pipe shall set into the recess of the next pipe. The ring shall be thoroughly compressed by jacking or by any other suitable method.

All joints shall be made with care so that their interior surface is smooth and consistent with the interior surface of the pipes. After finishing, the joint shall be kept covered and damp for at least four days.

2907 BACKFILLING

Trenches shall be backfilled immediately after the pipes have been laid and the jointing material has hardened. The backfill soil shall be clean, free from boulders, large roots, excessive amounts of sods or other vegetable matter, and lumps and shall be approved by the Engineer. Backfilling upto 300 mm above the top of the pipe shall be carefully done and the soil thoroughly rammed, tamped or vibrated in layers not exceeding 150 mm, particular care being taken to thoroughly consolidate the materials under the haunches of the pipe. Approved pneumatic or light mechanical tamping equipment can be used.

Filling of the trench shall be carried out simultaneously on both sides of the pipe in such a manner that unequal pressures do not occur.

In case of high embankment, after filling the trench upto the top of the pipe in the above said manner, a loose fill of a depth equal to external diameter of the pipe shall be placed over the pipe before further layers are added and compacted.

2908 HEADWALLS AND OTHER ANCILLARY WORKS

Headwalls, wing walls, aprons and other ancillary works shall be constructed in accordance with the details shown on the drawings or as directed by the Engineer. Masonry for the walls shall conform to Section 1300, 1400 or 1700 as applicable. Aprons shall conform to Section 2500.

2909 OPENING TO TRAFFIC

No traffic shall be permitted to cross the pipe line unless height of filling above the top of the pipe line is atleast 600 mm.

2910 MEASUREMENTS FOR PAYMENT

RCC pipe culverts shall be measured along their centre between the inlet and outlet ends in linear metres.

Selected granular material and cement concrete for pipe bedding shall be measured as laid in cubic metres. Ancillary works like headwalls, etc., shall be measured as provided for under the respective Sections.

2911 RATE

The Contract unit rate for the pipes shall include the cost of pipes including loading, unloading, hauling, handling, storing, laying in position and jointing complete and all incidental costs to complete the work as per these Specifications.

Ancillary works such as excavation including backfilling, concrete and masonry shall be paid for separately, as provided under the respective Clauses.

3000

Maintenance of Road

3001 GENERAL

The Specifications shall apply to all items of road maintenance works as required to be carried out under the Contract or as directed by the Engineer. The works shall be carried out in conformity with the relevant Specifications to the required level, grade and lines using approved materials. The works shall be carried out using light duty machinery or manual means provided the quality of the end product does not suffer. In execution of maintenance works, a reference is made to the IRC publications: “Manual for Maintenance of Roads” and “Code of Practice for Maintenance for Bituminous Surfaces of Highways, IRC:82-1982” for guidance and compliance wherever applicable. Wherever the Specifications are not clear, sound engineering practice shall be adopted to the satisfaction of the Engineer.

3002 RESTORATION OF RAIN CUTS

3002.1 Scope

The work shall consist of earthwork for restoration of rain cuts in the embankment and shoulders, using suitable material, and compacting the same.

3002.2 Materials

The material used for restoration of rain cuts shall consist of soil conforming to Clause 305.2.

3002.3 Construction Operation

The area affected by rain cuts shall be cleared of all loose soil and benched. The width of the benches shall be at least 300 mm and they shall extend continuously for a sufficient length. The height of the benches shall be in the range of 150-300 mm.

Fresh material shall be deposited in layers not exceeding 250 mm loose thickness and compacted so as to match with the benching at a moisture content close to the optimum. Compaction shall be carried out using suitable equipment such as plate compactors and rammers or by suitable implements handled manually. The finished work shall conform to alignment, levels and slopes as indicated in the drawing or as directed by the Engineer.

3002.4 Measurements for Payment

The earthwork for restoration of rain cuts shall be measured in cubic metres.

3002.5 Rate

The Contract rate for the item of earthwork for restoration of rain cuts shall be payment in full for carrying out the required operation including full compensation for:

i) Supply of material including all leads and lifts and the cost of arrangement of land;

ii) Setting out;

iii) Removal of loose material from the rain cuts;

iv) Benching of old earthwork; and

v) Compacting after adding required quantity of water.

3003 MAINTENANCE OF EARTHEN SHOULDER

3003.1 Scope

The work of maintenance of earthen shoulder shall include making up the irregularities/ loss of material on shoulder to the design level by adding fresh approved soil and compacting it with appropriate equipments or to strip excess soil from the shoulder surface as per the requirement of these Specifications.

3003.2 Material

The material to be added to the shoulder, if required, shall be a select soil conforming to Clause 305.

3003.3 Construction Procedure

This work shall involve:

i) Making up of the earthen shoulder by adding extra soil and compacting the same; and/or

ii) Stripping a layer of soil to achieve the required grade and level.

Wherever extra earth is required to be added, the earthen shoulder shall be stripped and loosened to receive fresh soil. The deficiency of thickness shall be made up in layers of loose thickness not exceeding 250 mm. Water shall be added, if required, to attain the optimum amount and the layer compacted by 80 to 100 kN smooth wheel roller, vibratory roller, hand roller, plate vibrator or hand rammer to obtain atleast 94 percent of the maximum dry density in accordance with IS:2720 (Part 8). The finished surface shall have the specified

cross slope and line in accordance with the drawing or as directed by the Engineer. The side slopes shall be trimmed to the required slope with the help of grader or manual methods using hand tools.

Wherever the earth is required to be excavated from the shoulder, this shall be done either using equipment like grader or by manual means using hand tools. The resulting surface shall be uniform and have a field density of atleast 94 per cent of maximum density obtained in accordance with IS:2720 (Part 8). If the surface is not uniformly compacted, it shall be excavated to a depth of 150 mm and the soil mixed with water if required and compacted at a moisture content close to the optimum to achieve 94 percent of maximum density as stated above.

3003.4 Measurement for Payment

Maintenance of earthen shoulder shall be measured in sq. metres.

3003.5 Rate

The Contract unit rate for maintenance of earthen shoulder shall be payment in full compensation for :

- i) furnishing earth required for making up of shoulders including all leads and lifts, cost of land and compaction;
- ii) excavation of earth as required and disposal of the earth at the location approved; and
- iii) all tools, equipments and incidentals to complete the work in accordance with these Specifications.

3004 BITUMINOUS WORK IN CONNECTION WITH MAINTENANCE AND REPAIR

3004.1 General

The scope and type of maintenance work to be carried out shall be in accordance with the provisions of the Contract or as instructed by the Engineer.

In all instances it will have been necessary to identify the causes of defects in order to permit effective repair. Where investigation work into the causes of defects is included in the Contract it shall be carried out in accordance with the appropriate provisions of these Specifications.

Maintenance treatments required under the Contract or instructed by the Engineer may include pothole and patch repair, crack-sealing, fog spray, dusting, slurry sealing, surface dressing, overlays and specialist repairs.

When the pavement to be maintained is intended to carry volumes of traffic in excess of 1.5 million msa the constructed materials (particularly patching and overlay materials) used in maintenance operations shall be of a standard not less than those specified for the original construction.

Traffic control during maintenance operations shall conform to the requirements of the Contract documents and Section 100.

3004.2 Filling Pot-holes and Patch Repairs

3004.2.1 Scope : This work shall include repair of pot-holes and patching of all types of bituminous pavement.

The work shall include the removal of all failed material, in the pavement courses and, if necessary, below the pavement, until the root cause of the failure is removed, the trimming of the completed excavation to provide firm vertical faces; the replacement of material of at least as high a standard as that which was originally specified for the pavement layer; the painting of tack coat on to the sides and bases of excavations prior to placing of any bituminous materials and the compaction, trimming and finishing of the surfaces of all patches to form a smooth continuous surface, level with the surrounding road.

3004.2.2 Materials : All materials used for the pot-hole and patch repair of bituminous surface and underlying layers shall be in accordance with thiese Specifications and shall be of the same type as specified for the original construction. A mix superior to the one on the existing surface may also be used for repair work. An emulsified bitumen/modified bitumen mix compatible with the existing layer shall also be considered appropriate.

The bituminous mixture used for such patch repairs shall be in accordance with the appropriate Clause of these Specifications. Materials to be used for patching shall always be of the same type and standard of construction as, or better than, the material being patched at the same level of construction. Materials used for patching shall never be of lesser bearing capacity nor of a greater porosity than the adjacent previous construction. Non-bituminous material must not be used for patching bituminous materials. Where modified binder is to be used, Clause 521 of these Specifications shall apply.

The grading of aggregates and bitumen content of the mix used for such patch repair shall be in accordance with Clause 501.

3004.2.3 Preparation of the area for pot-hole and patch repair : Each pot-hole and patch repair area shall be inspected and all loose material removed. The area shall be cut/trimmed either with jack hammers or with hand tools suitable for the purpose, such that the defective material responsible for the failure is all removed and such that the excavation is of a regular shape.

The edges of the excavation shall be cut vertically. The area shall be thoroughly cleaned with compressed air or any appropriate method approved by the Engineer to remove all dust and loose particles. Layers below the level of the bituminous construction shall be replaced using material of the equivalent specification to the original construction, which shall particularly include the specified standards of compaction. The area for bituminous construction shall be tacked or primed with cutback or emulsion depending upon whether the lower area is bituminous or granular in nature. The sides, however, are to be painted with hot tack coat material. The prime coat and tack coat shall conform to Clauses 502 and 503 of these Specifications, respectively.

3004.2.4 Backfilling operation : The mixture to be used in bituminous patching shall be either a hot mix or a cold mix in accordance with the appropriate Clauses of these Specifications. Mixing shall be done in a plant of suitable capacity. The bituminous mixture shall be placed in layers of thickness not more than 100 mm (loose) and shall be compacted in layers with roller/plate compactor/hand roller/rammer to the compaction standards defined in the appropriate Clauses of these Specifications. While placing the final layer, the mix shall be spread slightly proud of the surface so that after rolling, the surface shall be flush with the adjoining surface. If the area is large, the spreading and leveling shall be done using hand shovels and wooden straight edges. During the process of compaction, the surface levels shall be checked using a 3 m straight edge.

3004.2.5 Measurement for payment : Filling of pot-holes and patch repair shall be measured in sq.m.

3004.2.6 Rate : The contract unit rate for filling of pot-holes and patch repair shall be payment in full for :

i) furnishing all materials required;

ii) all works involved including excavation, trimming, back filling with any non-bituminous layers required, tacking, priming with cutback or emulsion, and back filling with bituminous materials;

iii) all labour, tools, equipment and incidentals to complete the work in accordance with the Specifications.

3004.3 Crack Sealing

3004.3.1 Scope : Crack sealing shall consist of one or more of the following operations as instructed under the Contract :

i) fog seal

ii) filling cracks with a binder, or a combination of crusher dust and a binder

iii) by treating the crack sealing as a patch repair.

3004.3.2 Fog seal

3004.3.2.1 Scope : Fog seal for use in maintenance work shall conform to the requirements of Clause 518 of these Specifications, and shall consist of an application of emulsified bitumen, without any aggregate cover for sealing fine hair-cracks or for rejuvenating oxidised bituminous surfaces. Areas having cracks with less than 3 mm width shall be considered for this treatment, unless otherwise instructed by the Engineer.

3004.3.2.2 Material : Bituminous emulsion for fog seal shall be of a slow setting type. Where modified binder is to be used, Clause 521 of these Specifications shall apply.

3004.3.2.3 Application : The area to be treated with fog seal shall be thoroughly cleaned using compressed air, scrubbers, etc. The cracks shall be cleaned with a compressed air jet to remove all dirt, dust, etc. The fog seal shall be applied at the rate of 0.5-1.0 litre/sq.m of emulsion, or as otherwise instructed by the Engineer, using equipment, such as, a pressure tank, flexible hose and spraying bar or lance. Traffic shall be allowed on to the surface only after the seal has set to a non-tacky and firm condition so that it is not picked up by the traffic.

3004.3.2.4 Measurement for payment : The fog seal work shall be measured in sq. metres, calculated from the dimensions of work instructed in the Contract or by the Engineer.

3004.3.2.5 Rate : The contract unit rate for application of fog seal shall be payment in full for :

i) supplying of fog seal material and all the operations for applying it; and

ii) all the labour, tools, equipment and incidentals to complete the work in accordance with these Specifications.

3004.3.3 Crack filling

3004.3.3.1 Scope : Crack filling shall be carried out using a binder of a suitable viscosity, normally a slow-curing bitumen emulsion, as instructed by the Engineer. For wider cracks, in excess of an average of 3 mm in width, the application of emulsion may be preceded by an application of crusher dust, or other fine material acceptable to the Engineer.

3004.3.3.2 Materials : Bitumen for use in crack sealing shall be of a slow curing type as instructed by the Engineer. Dust for crack sealing, when used, shall be crusher dust or some other suitable fine material approved by the Engineer, passing the 4.75 mm sieve but with a maximum of 10 percent passing the 0.075 mm sieve.

3004.3.3.3 Construction : If dust is to be used it shall be placed in the cracks before the application of binder and the cracks filled to a level approximately 5 mm below road surface level. The surface of the road shall be swept clear of dust prior to the application of binder. Binder shall be poured into the cracks, taking care to minimise spillage. If spillage onto the road surface does occur, dust shall be applied to the excess bitumen until it is blotted up.

3004.3.3.4 Measurement : Crack sealing shall be paid by the linear meter of crack as instructed by the Engineer.

3004.3.3.5 Rate : The contract unit rate for crack sealing shall be payment in full for :

i) supplying all necessary materials and for the work of applying them;

ii) all labour, tools, equipment and all incidentals necessary to complete the work according to these Specifications.

3004.3.4 Crack prevention courses : Clause 522 specifies crack prevention courses. These may be included to substantial maintenance treatments.

3004.4 Dusting

3004.4.1 Scope : Dusting shall consist of the application of crusher dust or other fine graded material approved by the Engineer to areas of road where bleeding of excess bitumen is occurring.

3004.4.2 Material : Dust shall consist of crusher dust or other graded fine material acceptable to the Engineer, and shall generally be finer than 3.0 mm with not more than 10 percent passing the 0.075 mm sieve.

3004.4.3 Dust shall be spread by manual application, to the areas of road defined by the Engineer. Dust shall generally be applied during the hottest part of the day and, when so instructed by the Engineer, surplus dust displaced by passing traffic shall be manually swept back onto the area where further bleeding of excess bitumen is apparent. Dust shall be applied at a nominal rate of 2.5 kg per square metre.

3004.4.4 **Measurement :** Dusting shall be paid for by the square metre of road surface instructed to be dusted by the Engineer.

3004.4.5 **Payment :** The Contract unit rate for dusting shall be payment in full for :

i) supplying all necessary materials and for the work of applying them;

ii) all labour, tools, equipment and all incidentals necessary to complete the work according to the Specifications.

3004.5 Slurry Seal

Slurry seal for use in maintenance work shall conform to the requirements of Clause 516. Manual methods of spreading and leveling may be used, subject to the prior agreement of the Engineer.

3004.6 Surface Dressing for Maintenance Work

Surface dressing for maintenance applications shall be carried out in conformity with the requirements of Clause 510, except that the use of small and portable equipment shall be permitted provided that it can be demonstrated, to the satisfaction of the Engineer, that it can produce work consistently in accordance with the requirements of these Specifications.

3004.7 Specialist Repairs

3004.7.1 Specialist repairs include repairs of localized areas of damage to materials for which repairs using normal hot-mix or cold-mix patching materials are inappropriate. Such specialist repairs will include repairs to mastic asphalt and stone mastic asphalt.

3004.7.2 In such cases, pot-hole and patch repairs shall be carried out in accordance with the provisions of Clause 3004.2 above, except that the construction to the mastic asphalt, stone mastic asphalt or other specialist material layer shall, subject to the instructions of the Engineer, be carried out in accordance with the provisions of the appropriate Clause of these Specifications.

3005 MAINTENANCE OF CEMENT CONCRETE ROAD

3005.1 Repair of Joint Grooves with Epoxy Mortar or Epoxy Concrete

3005.1.1 Scope : The work shall consist of repair of spalled joint grooves of contraction joints, longitudinal joints and expansion joints in a concrete pavement using epoxy mortar or epoxy concrete.

3005.1.2 Materials : The type/grade of epoxy compatible with the coefficient of thermal expansion of concrete shall be used with either processed fine aggregate or fine stone chips to produce a dry mix for repairing spalled or damaged edges.

3005.1.3 Repairing Procedure : Spalled or broken edges shall be shaped neatly with a vertical cut with chisels into the shape of rectangle. Small pneumatic chisels also may be used, provided the cutting depth can be controlled. The depth of the cut shall be the minimum to effect repair. After shaping the spalled area, it shall be cleaned and primed. The epoxy mortar/concrete is then applied using hand tools like trowels, straight edges, brushes etc. The repaired edge shall be in line with the joint groove and shall be flush with the concrete slabs. During the repair work, any damage noticed to the joint sealant shall be made good by raking out the affected portion and resealing.

3005.1.4 Traffic : Although the epoxy mixes set in 2-3 hours time, it is desirable to divert the traffic for 12 hours or as per the recommendation of the manufacturer.

3005.1.5 Measurements for payment : Repair of joint grooves shall be measured in linear metres.

3005.1.6 Rate : The Contract unit rate for repair of joint grooves with epoxy mortar or epoxy concrete shall be in full compensation for :

i) supply and application of epoxy primer, epoxy mortar or epoxy concrete;

ii) all tools, equipment and incidentals to complete the work in accordance with the Specifications.

3005.2 Repair Involving Removal of Old Joint Sealant and Sealing with Fresh Sealant in Cement Concrete Pavements

3005.2.1 Scope : The repair of sealant of contraction, longitudinal or expansion joints shall include removal of the existing sealant and resealing the joint with fresh sealant material.

3005.2.2 Material : Sealant material to be replaced shall be either hot poured rubberised bitumen or polysulphide type of sealant as per Clause 602.2.8. As per the recommendation of the manufacturer, appropriate type of primer also shall be applied.

3005.2.3 Repairing procedure : The existing sealant shall be raked out with the help of a metal raker such that most of the sealant is removed. Subsequently, the sealant stuck to the sides of the grooves shall be removed thoroughly either by using saw cutting machine so that grooves may be widened by 1 mm or by sand blasting. In no case the old sealant shall be present during resealing operation. If joint grooves are found inadequate in depth, they shall be deepened as directed by the Engineer.

Before commencing the sealing operation, compressed air shall be used to clean the joint grooves. A heat resistant, paper backed compressible debonding strip or tape should be inserted in accordance with the requirement of Clause 602.11.2. Sealant may be poured either using hand held pourer or using mechanized sealing machines. Sealants should not be heated directly but in double jacketed machine. All precautions and arrangements shall be taken not to spill the sealant on the concrete pavement. The sealant may be poured to a depth of 5 $\pm$ 2 mm from the pavement surface.

3005.2.4 Measurements for payment : Repair of joint sealant shall be measured in linear meters.

3005.2.5 Rate : Contract unit rate for repair of joint sealant shall be in full compensation for :

i) removal of old sealant, regrooving or sand blasting the sealing groove and placing of debonding strip or tape.

ii) all tools, equipments and incidentals to complete the work in accordance with the Specifications.

3100

Rainforce Earth

Annexure - 1

Table 3100-1 Selection Criteria based on height, durability and loading for vertical retaining walls

SYSTEM	CONDITION	Height of retaining wall		Design life		Loading		Seismic zone – IS 1893 (Part 1) :2002	
		< 10m	> 10m	20 to 100 yrs	< 20 yrs	Bridge or any heavy load (DL+LL)	IRC traffic loading (LL)	Zone II	Zone III, IV & V
Metallic reinforcement	Flexible face	Yes	Yes	Yes[6]	Yes	Yes	Yes	Yes	Yes
	Discrete concrete facing system	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Block wall	Yes	NO	NO[1]	Yes	NO[2]	Yes[3]	Yes[3]	NO[2]
	Rigid facing	Yes	NO	Yes	Yes	Yes	Yes	Yes	NO
Non-metallic (Synthetic) reinforcement	Flexible face	Yes	Yes	Yes[6]	Yes	NO	Yes	Yes	Yes
	Discrete concrete facing system [4]	Yes	NO[5]	Yes	Yes	NO	Yes	Yes	Yes
	Block wall	Yes	NO	NO[1]	Yes	NO	Yes[3]	Yes[3]	NO[2]
	RCC full height	Yes	NO	Yes	Yes	NO	Yes	Yes	Yes

1. Pre-cast block wall can be used only if the blocks are casted by wet mix concrete and not by dry mix method

2. Block wall system can be used only if the connection system is mechanical and all blocks shall be connected by main or secondary reinforcement

3. Only mechanical connection system shall be used no friction based connection system shall be used, all blocks in top two meter shall be connected with main or secondary reinforcement to cater for impact loading

4. Each facing panel shall be connected with minimum 2 layers (vertically) of reinforcement and for strap minimum 4 numbers of connector per panel (2 in horizontal and 2 in vertical elevations) shall be used. The main reinforcement shall be connected with panel by means of only mechanical arrangement. Concrete to concrete contact shall be avoided by provision of EPDM bearing pad in horizontal joints and clear gap in vertical joints.

5. Wall constructed with non-metallic (synthetic) reinforcement with height more than 6m shall not be permitted unless it can be satisfactorily demonstrated by previous experience that similar high structures has been constructed using exactly the same system by same system provider (height of wall, geometry, facing, reinforcement, connection, design methods, loading condition) and subject to approval of engineer in-charge.

6. All steel flexible facing for permanent structure (design life upto 100yrs) shall be hot dip galvanized (minimum 400 gm/sqm). For non-metalic (synthetic) wrap around facing, a perennial vegetation cover with/without erosion control blanket shall be ensured.

Table 3100-2 Decision chart for reinforcement type according to environment and application

		Environment / Type of fill					
		Low Chlorides and Sulphates High resistivity	High Chloride and Sulphates Marine Application	Fine Soils treated with cement or lime	Recycled Concrete	Acidic fills	Low Extensibility High Walls Abutments
steel	Black Steel	cf table below		10 < pH < 12	9 < pH <11	2 < pH < 5	
		< 20 yrs 5 < pH < 10	NO	NO	NO	NO	YES
	Galvanized steel	100 yrs 5 < pH < 10	NO	NO	NO	NO	YES
Polyester (PET) yarn		100 yrs , 4 < pH < 9		NO		YES	NO
PVA, PP & HDPE		100 yrs , pH > 3					NO

Table 3100-3 Special condition for use of metallic (steel) reinforcement

Environment	Type of fill	Electrochemical characteristics		
		pH	Resistivity (Ohm.cm)	Maximum salt contents(ppm)
Out of water	Draining or granular	5 TO 10	> 1000	Chlorides < 100 Sulfates < 200
Fresh Water	Granular	5 TO 10	> 3000	

Table 3100-4 Selection criteria based on foundation condition

The short term and long term performance of reinforced soil wall structures depends primarily on foundation soil condition. Hence, it is most important to select appropriate technology depending of foundation soil condition and also type of improvement measures. Decision chart for reinforcement type according to foundation / improved foundation condition:

FOUNDATION CONDITION	Hard, Soft or Disintegrated Rock	Dense to medium dense Sand	Loose sand / clay	Improved foundation with PVD, Synthetic reinforcement	Improved foundation with Stone column/pile	Foundation treated with replacement
	Expected total settlement < 50mm All types of retaining wall, slope and abutment[1] can be constructed		Expected total settlement > 50mm Only metallic reinforcement upto a maximum height of 7.0m for vertical wall. No pure abutment is recommended. Synthetic reinforcement with flexible facing upto a maximum height of 7.0m for vertical wall and 20m for steep slope.		All types of retaining wall, slope and abutment[1] can be constructed.	

1. The allowable post construction settlement (after construction of bridge deck) shall be restricted to maximum 25mm.

3200

3201. SCOPE

The specifications shall apply to soil nailing works as required to be carried out under the Contract or as directed by the Engineer.

3202. NAIL INSTALLATION METHODS

3202.1. Generally used soil nail installation techniques in practice are: (i) drilled and grouted soil nails, and (ii) driven soil nails. Grouted nails are recommended for all types of soil nail walls applications; and in particular, for walls with vertical height more than 7 m. Driven nails shall only be used when wall heights are smaller (less than or upto 7.0 m). The major difference between the two is the pullout resistance of the soil nails and grouted soil nails are expected to have higher pull out resistance. Pull out test is desirable to check the values of pullout resistance which is useful in soil nail design.

3202.2. Drilled and grouted soil nails (or simply grouted nails), are approximately 75 mm to 200 mm diameter nail holes drilled in the soil mass to be retained, which shall be followed by placing of steel reinforcement bars (tendon) and the grouting of the drill hole.

3202.3. Driven soil nails are relatively small in diameter (20 mm to 25 mm) and are mechanically driven into the ground. They are usually spaced approximately 0.5 m to 1.0 m apart.

3203. CONSTRUCTION MATERIALS

Following covers the general materials required for the construction of typical soil nailing structure.

3203.1. Reinforcement bar (nail or tendon)

The reinforcing element (tendon) shall be high strength steel reinforcing bar conforming to IS: 1786 with a characteristic tensile strength of 415 MPa or higher which may be threaded at one end. Minimum recommended diameter of reinforcement bar (tendon) is 16 mm.

3203.2. Nail head

The nail head shall comprise of following main components: the bearing-plate, hex nut, and washers; and the headed-stud. The bearing plate with a central hole (with diameter greater than reinforcement bar) shall be of minimum Fe250 grade steel, typically square in shape with 200 to 250 mm side dimension and 19 mm thickness. Washers and nuts shall be made of steel with a grade consistent with that of the nail bar commonly of 415 MPa or higher. Nuts may be tightened with a hand-wrench. The headed-stud connection may consist of four headed studs welded near the four corners of the bearing plate to provide anchorage of the nail head into the permanent facing. For temporary walls, the bearing plate shall be on the outside face of the shotcrete facing.

3203.3. Grout

Grout for soil nails is required to fill the annular space between the nail bar and the surrounding ground, and for shotcreting of the temporary facing. Grout for soil nail walls is commonly a neat cement grout with the water/cement ratio typically ranging from 0.4 to 0.5. Grout mix shall be prepared in accordance with IS: 9012. Grout shall have a minimum 28 days characteristic strength of 20 MPa. For filling up nail holes, grout shall be pumped

shortly after the nail bar is placed in the drillhole to reduce the potential for hole squeezing or caving. In solid nail bar applications, the grout may be injected by tremie methods through a grout pipe, which is previously inserted to the bottom of the drillhole, until the grout completely fills the drillhole.

3203.4. Centralizers

Centralizers are devices made of polyvinyl chloride (PVC) or other synthetic materials that are installed at various locations along the length of each nail bar to ensure that a minimum thickness of grout completely covers the nail bar. Centralizers shall be installed at regular intervals, typically not exceeding 2.5 m, along the length of the nail and at a distance of about 0.5 m from each end of the nail.

3204. FACING TYPES

Soil nail walls are generally provided with two types of facings: (a) temporary facing and (b) permanent facing.

3204.1. Temporary facing

Temporary facing shall be constructed by providing reinforcement in the form of welded wire mesh (conforming to IS:1566) throughout the wall face, and by additional bearing plates (*see* Clause **3203.2.**) and waler bars (rebars of smaller lengths placed in the vicinity of nail head) at the nail heads; which is, subsequently shotcreted in accordance with IS: 9012. Overall temporary facing thickness shall vary from 75 mm -200 mm.

3204.2. Permanent facing

Permanent facing may be constructed as cast-in-place reinforced cement concrete conforming to IS: 456, precast concrete or any suitable material to achieve desired strength and aesthetics. Reinforcement in the permanent facing may be adopted in the form of welded wire mesh or reinforcement bars in either direction. Permanent facing shall be connected to the temporary facing by means of headed-studs (usually four numbers per plate) welded on the bearing plates installed during construction temporary facing. Minimum thickness of permanent facing shall not be less than 200 mm.

3205. CONSTRUCTION SEQUENCE

3205.1. Typical sequence of construction of a soil nail wall shall be in accordance with following steps:

Step 1: Excavation of initial cut of 1.0 m -2.0 m depending upon the capacity of in-situ soil to stand unsupported for about 12-24 hrs;
Step 2: Drilling hole for nail;
Step 3: Installation of nails followed by grouting and placing of drainage strip;
Step 4: Placing of construction facing and installation of bearing plates;
Step 5: Repetition of process till final level is reached; and
Step 6: Placing of final facing.

3206. GEOTECHNICAL ASPECTS

3206.1 Soil investigation

For soil nail walls more than 30 m long, exploratory borings should be spaced between 30 to 60 m along the proposed centerline of the wall. For walls less than 30 m long, at least one boring is necessary along the proposed centerline of the wall. Borings are also necessary in front and behind the proposed wall. Borings behind the wall should be located within a distance up to 1 to 1.5 times the height of the wall behind the wall and should be spaced up to 45 m along the wall alignment. Borings in front of the wall should be located within a distance up to 0.75 times the wall height in front of the wall and should be spaced up to 60 m along the wall alignment. The depth of borings should extend at least one full wall height below the bottom of the excavation.

3206.2. Bond strength

The bond strength is the mobilized shear resistance along the soil-grout interface. The bond strength adopted for the design of soil nails is commonly based on conservative estimates obtained from field correlation studies and local experience in similar conditions. Consequently, some percentage of the soil nails shall be load tested according to standard procedure (pullout tests) in the field to verify bond strength design.

3206.3. Suitable in-situ ground conditions

Following are the in-situ conditions considered favorable for the prospective use of soil nailing technique.

(a) Soil shall be able to stand unsupported to a depth of about 1 m – 2 m high vertical or nearly vertical cut for 12-24 hours.

(b) Groundwater table shall be sufficiently below level of the lowermost soil nail at all cross-sections.

(c) Favorable soils: Stiff to hard fine –grained soils, dense to very dense granular soils with some apparent cohesion, weathered rock with no weakness planes and glacial soils.

3207. ANALYSIS OF FAILURE MODES

3207.1. Analysis of various failure modes of soil nail structures shall be performed using allowable stress design methodology in accordance with IRC publication "*Interim Guidelines for Soil Nailing Technique in Highway Engineering Applications*" or any other state-of-art standard for analysis, design and construction of soil nail walls. For rigorous analyses, use of computational tools based on advanced numerical techniques such as finite element method, is strongly recommended.

3208. INITIAL DESIGN CONSIDERATIONS

3208.1. Wall layout

Establish the layout of the soil nail wall, including: (1) wall height; (2) length of the wall; (3) backslope; and (4) wall face batter. Wall face batter typically ranges from 0º to 10º. The evaluation of the wall layout also includes developing longitudinal profile of the wall, locating

wall appurtenances (e.g., traffic barriers, utilities, and drainage systems), and establishing ROW limitations.

3208.2. Soil nail vertical and horizontal spacing

Typically, same nail spacing can be adopted in both horizontal S_h and vertical S_{-v} directions. Nail spacing ranges from 1.25 to 2 m (commonly 1.5 m) for conventional drilled and grouted soil nails, and as low as 0.4 m for driven nails. As a general rule, soil nail spacing in horizontal and vertical direction must be such that each nail has an influence area $S_h \times S_v \le 4\,m^2$.

3208.3. Soil nail pattern on wall face

The soil nail pattern on wall face may be adopted as one of the following: (1) square (or rectangular); (2) staggered in a triangular pattern; and (3) irregular (at limited locations) depending upon the ease of construction and site-specific constraints.

3208.4. Soil nail inclination

Soil nails are typically installed at an inclination ranging from 0 to 30 degrees from horizontal with a typical inclination of 10-25 degrees.

3208.5. Soil nail length and distribution

The distribution of soil nail lengths in a soil nail wall can be selected as either uniform (i.e., only one nail length is used for the entire wall), or variable, where different nail lengths may be used for individual soil nail levels within a wall cross section. Uniform nail pattern is recommended for most applications.

$DL + EQ + IL$

3209. OTHER DESIGN CONSIDERATIONS

3209.1. Loads and load combinations

Soil nail walls used on typical highway projects are typically subjected to the following different loads during their service life: (i) Dead loads DL (e.g., weight of the soil nail wall system, lateral earth pressure, weight of a nearby above-ground structure); (ii) Live loads LL (e.g., traffic loads); (iii) impact loads IL (e.g., vehicle collision on barriers above soil nail wall); and (iv) earthquake loads EQ. Following load combinations are recommended to assess the most critical loading condition:

(a) $DL + LL$

(b)

(c)

For earthquake loads, allowable stresses shall be increased by 133 percent from the values obtained with factors of safety for static loads.

3209.2. Permissible soil nail wall deformations

The maximum permissible lateral deformation at the top of the soil nail walls constructed in weathered rock and stiff soils is 0.1%H; sandy soils is 0.2%H and for fine-grained soils is 0.3%H. Under no circumstances maximum permissible lateral deformation shall exceed 0.3% H, where: H is the vertical height of the soil nail wall. Permissible vertical deformation (i.e., settlement) shall be considered to be same as the permissible horizontal deformation.

3209.3. Drainage measures

3209.3.1. Short term drainage measures

Surface water and groundwater must be controlled both during and after construction of the soil nail wall. A surface water interceptor ditch, excavated along the crest of the excavation and lined with concrete, is a recommended element for controlling surface water flows. Additionally, if ground water impacts are temporary or localized, suitable dewatering measures may be taken for lowering the groundwater table

3209.3.2. Long term drainage measures

Long term drainage shall be provided by means of the drainage system comprising of: (i) vertical geo-composite drain strips placed suitably along the face of wall; (ii) weep holes in the form of perforated PVC pipes of typical diameter as 50-100 mm and 300-600 mm length, placed through the face at the location of expected localised seepage; (iii) provision of horizontal or slightly inclined drain pipes of typical diameter 50 mm installed at the locations where it is necessary to control the groundwater pressures imposed on the retained soil mass; (iv) installation of permanent interception ditch behind the wall at its crest to prevent surface water runoff from infiltrating behind the wall or flowing over the wall edge; and (v) provision of a vegetative protective cap/cover to reduce or prevent water infiltration into the soil.

3209.4. Corrosion protection

Corrosion potential of the soil must be evaluated for all permanent soil nail walls and, in some cases, for temporary walls.

Corrosion protection measures: (a) Specify a minimum grout cover of 25 mm between the reinforcement nail bar and the soil; (b) recommend epoxy coating of minimum thickness 0.4 mm on the nail bars shall be applied by the manufacturer prior to shipment of nails to the construction site, which is, subsequently to be encased in grout cover; and (c) adopt other site-specific suitable corrosion protection measures.

3210. FIELD PULLOUT TESTING

3210.1. Field pullout testing of soil nails shall be conducted (a) to verify that the nail design loads can be carried without excessive movements and with an adequate safety factor for the service life of the structure, and (b) to verify the adequacy of the contractor’s drilling, installation, and grouting operations prior to and during construction of production soil nails.

3210.1. Types of field pullout tests

Depending upon the type of test being performed, the maximum test load, the load increments, and the time that each load increment is held shall be determined. To prevent chances of explosive failure of the steel, in no case, the soil nail tendon be stressed to more than 80 percent of its minimum ultimate tensile strength for grade Fe415 steel, or more than 90 percent of the minimum yield strength for grade Fe500 steel.

3210.1.1. Verification test

A verification test on soil nail is performed: (a) to determine the ultimate bond capacity (if carried to pullout failure); (b) verify the design bond factor of safety, and (c) to determine the soil nail load at which excessive creep occurs. Verification tests are generally conducted on non-production "sacrificial" nails as a *first order of work prior to construction*.

3210.1.2. Proof test

A proof test is typically performed on a specified number of the total number of production soil nails installed. Typically, successful proof tests shall be performed on 5 percent of the production nails in each row or a minimum of 1 test per row. Proof tests provide information necessary to evaluate the ability of production soil nails to safely withstand design loads without excessive structural movement or long-term creep over the structure's service life.

3210.1.3. Creep Test

Creep tests are generally performed as part of a verification or proof test to ensure that nail design loads can be safely carried throughout the structure service life.

3211. MEASUREMENT FOR PAYMENT

Measurements for earthwork shall conform to IS: 1200(Part I), concrete work shall conform to IS: 1200(Part II) and steelworks shall conform to IS: 1200(Part VIII). Measurement of facia shall be in sq. metres.

3212. RATES

Rates for labour, machinery and various structural components shall conform to the local schedule of rates in practice.

3213. REFERENCES

IS:1200(Part I)-1992. Method of measurement of building and civil engineering works – EARTHWORK (fourth revision).

IS:1200(Part II)-1974. Method of measurement of building and civil engineering works – CONCRETE WORKS (third revision).

IS:1200(Part VIII)-1993. Method of measurement of building and civil engineering works – STEELWORK AND IRONWORK (fourth revision).

IS:1566-1982. Specification for hard-drawn steel wire fabric for concrete reinforcement (second revision incorporating amendments nos. 1, 2 and 3).

IS:1786-1985. Specification for high strength deformed steel bars and wires for concrete reinforcement (third revision).

IS:456-2000. Plain and reinforced concrete – code of practice (fourth revision).

IS:9012-1978 Recommended practice for shotcreting (fourth reprint).

IRC publication "*Interim Guidelines for Soil Nailing Technique in Highway Engineering Applications*" **(to be published)**.

3300

Use of New Materials & Technique

3300 General

Number of new materials in the various fields of Highway Sector are emerging in the market. The characteristic attributes of all these materials which are by and large additive in nature are mostly based on laboratory test results and / or are based on application in some other countries. Some of these materials are not provided / covered under International Specifications also. The Promoters/Manufacturers of these materials however, have claimed substantial quality improvement of existing materials in Indian conditions, provided we have them in terms of prescribed doses.

Ministry has encouraged utilization of such emerging road construction materials and issued guidelines vide Ministry's circular No RW/NH-35068/1/1996-S&R dated 1-3-1999. The Indian Roads Congress has through its Committee has accredited new materials as given in the Appendix based on the details, including test results submitted by the Manufacturer / Promoters of such materials. These accreditations are with the stipulations of a field trial using such materials with the idea that necessary feed back from use of these materials shall help the IRC and Ministry to frame process Specifications typically to meet Indian conditions. The accreditation of materials shall continue in future also and will be published in the monthly journal of IRC and shall get added to the Appendix 3300/1.

The manual for highway construction for two/ four laning through public-private partnership published by IRC also provides freedom to the concessionaires to use the new materials at their own risk and cost. If the Specification directs for the use of these materials in an extensive manner to establish their efficacy and including cost effectiveness. These materials can subsequently added to the Specifications after their efficacy and cost effectiveness are established under Indian conditions.

The user Agencies may suitably make use of the new materials accredited by IRC. Use of only such materials is recommended which are recognized in the Specifications of Roads /Highways of the Country of origin and /or manufacture of such new materials. It is recommended that approval of the Technical Up-gradation Committee of the Ministry of Road Transport & Highways may be obtained for use of such materials. Technical Up-gradation Committee of the Ministry shall also resolve any doubts in this regard.

Appendix 1

LIST OF IRC PUBLICATIONS REFERRED TO IN THE SPECIFICATIONS

Number Designation	Title
IRC:2-1968	Route Marker Signs for National Highways (First Revision)
IRC:5-1998	Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design (Seventh Revision)
IRC:6-2000	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses (Fourth Revision)
IRC:8-1980	Type Designs for Highway Kilometre Stones (Second Revision)
IRC:10-1961	Recommended Practice for Borrowpits for Road Embankments Constructed by Manual Operation
IRC:12-2009	Guidelines for Access, Location and Layout of Roadside Fuel Stations and Service Stations (Third Revision)
IRC:14-2004	Recommended Practice for Open Graded Premix Carpets (Third Revision)
IRC:16-2008	Standard Specifications and Code of Practice for Prime and Tack Coat (Second Revision)
IRC:17-1965	Tentative Specification for Single Coat Bituminous Surface Dressing
IRC:18-2000	Design Criteria for Prestressed Concrete Road Bridges (Post-Tensioned Concrete) (Third Revision)
IRC:19-2005	Standard Specification and Code of Practice for Water Bound Macadam (Third Revision)
IRC:20-1966	Recommended Practice for Bituminous Penetration Macadam (Full Grout)
IRC:21-2000	Standard Specifications and Code of Practice for Road Bridges, Section III – Cement Concrete (Plain and Reinforced) (Third Revision)
IRC:22-2008	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design) (Second Revision)
IRC:23-1966	Tentative Specification for Two Coat Bituminous Surface Dressing
IRC:24-2001	Standard Specifications and Code of Practice for Road Bridges, Section V – Steel Road Bridges (Second Revision)

Number Designation	Title
IRC:25-1967	Type Designs for Boundary Stones
IRC:26-1967	Type Design for 200-Metre Stones
IRC:27-2009	Specifications for Bituminous Macadam(First Revision)
IRC:29-1988	Specification for Bituminous Concrete (Asphaltic Concrete) for Road Pavement (First Revision)
IRC:30-1968	Standard Letters and Numerals of Different Heights for Use on Highway Signs
IRC:35-1997	Code of Practice for Road Markings (with Paints) (First Revision)
IRC:36-1970	Recommended Practice for Construction of Earth Embankments for Road Works
IRC:37-2001	Guidelines for the Design of Flexible Pavements (Second Revision)
IRC:40-2002	Standard Specifications and Code of Practice for Road Bridges, Section IV – (Brick, Stone and Block Masonry) (Second Revision)
IRC:45-1972	Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges
IRC:47-1972	Tentative Specification for Built-up Spray Grout
IRC:48-1972	Tentative Specification for Bituminous Surface Dressing Using Precoated Aggregates
IRC:50-1973	Recommended Design Criteria for the Use of Cement Modified Soil in Road Construction
IRC:51-1992	Guidelines for the Use of Soil Lime Mixes in Road Construction (First Revision)
IRC:56-1974	Recommended Practice for Treatment of Embankment Slopes for Erosion Control
IRC:63-1976	Tentative Guidelines for the Use of Low Grade Aggregates and Soil Aggregates Mixtures in Road Pavement Construction
IRC:67-2001	Code of Practice for Road Signs (First Revision)
IRC:72-1978	Recommended Practice for Use and Upkeep of Equipment, Tools and Appliances for Bituminous Pavement Construction
IRC:75-1979	Guidelines for the Design of High Embankments

Number Designation	Title
IRC:78-2000	Standard Specifications and Code of Practice for Road Bridges, Section VII – Foundations and Substructure (Second Revision)
IRC:79-1981	Recommended Practice for Road Delineators
IRC:82-1982	Code of Practice for Maintenance of Bituminous Surfaces of Highways
IRC:83-1999(Part-I)	Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings, Part I : Metallic Bearings (First Revision)
IRC:83-1987(Part II)	Standard Specifications and Code of Practice for Road Bridges, Section IX – Bearings, Part II: Elastomeric Bearings
IRC:87-1984	Guidelines for the Design and Erection of Falsework for Road Bridges
IRC:89-1997	Guidelines for Design and Construction of River Training & Control Works for Road Bridges (First Revision)
IRC:90-1985	Guidelines of Selection, Operation and Maintenance of Bituminous Hot Mix Plant
IRC:93-1985	Guidelines on Design and Installation of Road Traffic Signals
IRC:111-2009	Specifications for Dense Graded Bituminous Mixes
IRC:SP:11-1984	Handbook of Quality Control for Construction of Roads and Runways (Second Revision)
IRC:SP:21-2009	Guidelines for Landscaping and Tree Plantation (First Revision)
IRC:SP:30-2009	Manual on Economic Evaluation of Highway Projects in India (Second Revision)
IRC:SP:31-1992	New Traffic Signs
IRC:SP:53-2002	Guidelines on Use of Polymer and Rubber Modified Bitumen in Road Construction (First Revision)
IRC:SP:55-2001	Guidelines for Safety in Construction Zones
IRC:SP:58-2001	Guidelines for Use of Flyash in Road Embankments
IRC:SP:59-2002	Guidelines for Use of Geotextiles in Road Pavements and Associated Works
IRC:SP:60-2002	An Approach Document for Assessment of Remaining Life of Concrete Bridges
IRC:SP:61-2004	An Approach Document on Whole Life Costing for Bridges in India

Number Designation	Title
IRC:SP:62-2004	Guidelines for the Design and Construction of Cement Concrete Pavement for Rural Roads
IRC:SP:63-2004	Guidelines for the Use of Interlocking Concrete Block Pavement
IRC:SP:64-2005	Guidelines for the Analysis and Design of Cast-in-Place Voided Slab Superstructure
IRC:SP:65-2005	Guidelines for Design and Construction of Segmental Bridges
IRC:SP:66-2005	Guidelines for Design of Continuous Bridges
IRC:SP:67-2005	Guidelines for Use of External and Unbonded Prestressing Tendons in Bridge Structures
IRC:SP:68-2005	Guidelines for Construction of Roller Compacted Concrete Pavements
IRC:SP:69-2005	Guidelines & Specifications for Expansion Joints
IRC:SP:70-2005	Guidelines for the Use of High Performance Concrete in Bridges
IRC:SP:71-2006	Guidelines for Design and Construction of Pretensioned Grider of Bridges
IRC:SP:74-2007	Guidelines for Repair and Rehabilitation of Steel Bridges
IRC:SP:75-2008	Guidelines for Retrofitting of Steel Bridges by Prestressing
IRC:SP:76-2008	Tentative Guidelines for Conventional, Thin and Ultra Thin Whitetopping
IRC:SP:78-2008	Specifications for Mix Seal Surfacing (MSS) Close-Graded Premix Surfacing (CGPS)
IRC:SP:79-2008	Tentative Specifications for Stone Matrix Asphalt
IRC:SP:80-2008	Guidelines for Corrosion Prevention, Monitoring and Remedial Measures for Concrete Bridge Structures
IRC:SP:81-2008	Tentative Specification for Slurry Seal and Microsurfacing
IRC:SP:83-2008	Guidelines for Maintenance, Repairs & Rehabilitation of Cement Concrete Pavements Ministry of Shipping & Transport (Roads Wing) Handbook on Road Construction Machinery
HRB SR.No.11, 1992	State of the Art: Granular and Bound Bases and Sub-Bases

Appendix-2

LIST OF INDIAN AND FOREIGN STANDARDS REFERRED TO IN THE SPECIFICATIONS

Number Designation	Title
	(A) INDIAN STANDARDS
IS:5-2004	Colour for ready mixed paints and enamels (Fifth revision)
IS:73-2006	Viscosity Grade Bitumen Specifications
IS:164-1981	Ready mixed paints, brushing, for road marking, to Indian Standard Colour No.356 Golden yellow, white and black
IS:210-1993	Grey iron castings (fourth revision)
IS:215-1995	Road tar specification (third revision)
IS:217-1988	Specification for Cutback Bitumen (second revision)
IS:269-1989	Specification for 33 grade ordinary Portland cement (fourth revision)
IS:278-1978	Specification for Galvanized steel barbed wire for fencing (third revision)
IS:280-2006	Specification for Mild steel wire for general engineering purposes (fourth revision)
IS:334-2002	Glossary of terms relating to bitumen and tar (third revision)
IS:383-1970	Specification for Coarse and fine aggregates from natural sources for concrete (second revision)
IS:432-1982	Mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement
Part I	Specification for Mild steel and medium tensile steel bars (third revision)
Part II	Hard-drawn steel wire (third revision)
IS:443-1975	Methods of sampling and test for rubber hoses (second revision)
IS:454-1994	Specification for Cutback bitumen from Waxy Crude-Specification (second revision)
IS:455-1989	Specification for Portland stag cement (fourth revision)
IS:456-2000	Plain and reinforced concrete – Code of Practice (Fourth revision)

Number Designation	Title
IS:458-2003	Precast Concrete pipes (with and without reinforcement) – specification (third revision)
IS:460-1985	Specification for test sieves:
IS:508-1987	Specification grease graphited (fourth revision)
IS:516-1959	Methods of test for strength of concrete
IS:702-1988	Industrial bitumen (second revision)
IS:736-1986	Wrought aluminium and aluminium alloys, plates for general engineering purposes (third revision)
IS:814-2004	Covered electrodes for manual metal arc welding of carbon and carbon manganese steel (sixth revision)
IS:1030-1998	Carbon steel castings for general engineering purposes (fifth revision)
IS:1077-1992	Common burnt clay building bricks (fifth revision)
IS:1124-1974 gravity and	Method of test for water absorption apparent specific porosity of natural building stones (first revision)
IS:1129-1972	Dressing of natural building stones (first revision)
IS:1148-1982 purposes	Hot rolled rivet bars (upto 40 mm dia) for structural (third revision)
IS:1149-1982	High tensile rivet bars for structural purposes (third revision)
IS:1195-2002	Bitumen mastic for flowing (second revision)
IS:1199-1959	Method of sampling and analysis of concrete
IS:1201:1978	Sampling – (see IS:1201 to IS:1220)
IS:1203-1978	Determination of penetration (first revision) (see IS:1201 to IS:1220)
IS:1205-1978	Determination of softening point (first revision) (see IS:1201 to IS:1220)
IS:1206 : Part 1 : 1978	Determination of viscosity: Part 1 Industrial viscosity - (see IS 1201 to IS 1220)
IS:1206 : Part 2 : 1978	Determination of viscosity: Part 2 Absolute viscosity - (see IS 1201 to IS 1220)
IS:1206 : Part 3 : 1978	Determination of viscosity: Part 3 Kinematic viscosity - (see IS 1201 to IS 1220)

Number Designation	Title
IS:1208-1978	Determination of ductility (first revision) (see IS:1201 to IS:1220)
IS:1209-1978	Determination of flast point and fire point (first revision) (see IS:1201 to IS:1220)
IS:1212-1978	Determination of loss on heating (first revision)
IS:1216-1978	Determination of solubility in carbon disulphide trichoroethylene (first revision)
IS:1217-1978	Determination of mineral matter ash) (first revision)
	(see IS:1201 to IS:1220)
IS 1239 : Part 1 : 2004	Steel Tubes, Tubulars and Other Wrought Steel Fittings - Specification - Part 1 : Steel Tubes
IS 1239 : Part 2 : 1992	Mild steel tubes, tubulars and other wrought steel fittings, Part 2 Mild steel tubulars and other wrought steel pipe fittings
IS 1364 : Part 1 : 2002	Hexagon Head Bolts, Screws and Nuts of Product Grades A and B - Part 1 : Hexagon Head Bolts (Size Range M 1.6 to M 64)
IS 1364 : Part 2 : 2002	Hexagon Head Bolts, Screws and Nuts of Product Grades A and B - Part 2 : Hexagon Head Screws (Size Range M 1.6 to M 64)
IS 1364 : Part 3 : 2002	Hexagon Head Bolts, Screws and Nuts of Product Grades A and B - Part 3 : Hexagon Nuts, Style 1 (Size Range M 1.6 to M 64)
IS 1364 : Part 4 : 2003	Hexagon Head Bolts, Screws and Nuts of Product Grades A and B - Part 4 : Hexagon Thin Nuts (Chamfered) (Size Range M1.6 to M64)
IS 1364 : Part 5 : 2002	Hexagon Head Bolts, Screws and Nuts of Product Grades A and B - Part 5 : Hexagon Thin Nuts - Product Grade B (Unchamfered) (Size Range M 1.6 to M 10)
IS 1364 : Part 6 : 2002	Hexagon Head Bolts, Screws and Nuts of Product Grades A and B - Part 6 : Hexagon Nuts, Style 2
IS 1367 : 2002	(Part 1 to 20) Technical Supply Conditions for Threaded Steel Fasteners
IS:1387-1993	General requirements for the supply of metallurgical materials (second revision)

Number Designation	Title
IS:1398-1982	Packing paper, waterproof, bitumen-laminated (second revision)
IS: 1448 (Part 1 to 152)	Methods of Test for Petroleum and its Products
IS:1477	Code of practice for painting of ferrous metals in buildings
Part 1-1971	Pretreatment (first revision)
Part 2-1971	Painting (first revision)
IS:1489-1991	Specification for Portland-pozzolana cement
Part 1	Flyash based (third revision)
Part 2	Calcined clay based (third revision)
IS:1498-1970	Classification and identification of soils for general engineering purposes (first revision)
IS:1514-1990	Methods of sampling and test for quick lime and hydrated lime (first revision)
IS:1732-1989	Dimensions for round and square steel bars for structural and general engineering purposes (second revision0
IS:1785-1983	Plain hard-drawn steel wire for prestressed concrete
Part I	Cold-draws stress relieved wire (second revision)
Part II	As drawn wire
IS:1786-1985	High strength deformed steel bars and wires for concrete reinforcement (third revision)
IS 1838 : Part 1 : 1983	Specification for preformed fillers for expansion joint in pavements and structures (non extruding and resilient type): Part 1 Bitumen impregnated fibre
IS 1838 : Part 2 : 1984	Specification for preformed fillers for expansion joint in pavements and structures (non extruding and resilient type) Part 2 CNSL Aldehyde resin and coconut pith
IS:1888-1982	Method of load tests on soils (second revision)
IS:2004-1991	Carbon steel forging for general engineering purposes (third revision)
IS:2062-2006	**Steel to general structural purpose (fifth revision)**
IS:2116-1980	Sand for masonry mortars (first revision)
IS:2131-1981	Methods for standard penetration test for soils (first revision)

Number Designation	Title
IS:2250-1981	Code of practice for preparation and use of masonry mortars (first revision)
IS:2386-1963	Methods of test for aggregates for concrete
Part 1	Particle size and shape
Part 2	Estimation of deleterious materials and organic impurities
Part 3	Specific gravity, density, voids, absorption and bulking
Part 4	Mechanical properties
Part 5	Soundness
Part 6	Measuring mortar making properties of fine aggregates
Part 7	Alkali – aggregate reactivity
Part 8	Petrographic examination
IS:2720	Methods of test for soils
Part 2-1973	Determination of water content (second revision)
Part 3-1980	Determination of specific gravity (first revision)
Section I	Fine grained soils
Section II	Medium and coarse grained soils
Part 4-1985	Grain size analysis (second revision)
Part 5-1985	Determination of liquid and plastic limits (second revision)
Part 7-1980	Determination of moisture content/dry density relation using light compaction (second revision)
Part 8-1983	Determination of water content-dry density relation using heavy compaction (second revision)
Part 10-1991	Determination of unconfined compressive strength (second revision0
Part 13-1986	Direct shear test (second revision)
Part 14-1983	Determination of density index (relative density of cohesionless soils (first revision)
Part 16-1987	Laboratory determination of CBR (second revision)
Part 27-1977	Determination of total soluble sulphates (first revision)
Part 28-1974	Determination of dry density of soils in-place by the sand replacement method (first revision)

Number Designation	Title
Part 29-1975	Determination of dry density of soils in-place by core cutter method (first revision0
Part 37-1976	Determination of sand equivalent values of soils and fine aggregates
Part 40-1977	Determination of free swell index of soils
IS 3117 : 2004	**Bitumen Emulsion for Roads and Allied Applications (Anionic Type) - Specification**
IS:3466-1988	Specification for Masonry cement (second revision)
IS:3764-1992	Code of safety for excavation work (first revision)
IS:4138-1977	Safety code for working in compressed air (first revision)
IS:4332	Method of test for stabilized soils
Part I-1967	Methods of sampling and preparation of stabilized soils for testing
Part 3-1967	Test for determination of moisture content-dry density relation for stabilized soil mixtures
Part 4-1968	Wetting and drying and, freezing and thawing tests for compacted soil-cement mixtures
Part 5-1970	Determination of unconfined compressive strength of stabilized soil
Part 7-1973	Determination of cement content of cement stabilized soils
Part 8-1969	Determination of lime content of lime stabilized soils
IS:4434-1978	Code of practice for in-situ vane shear test for soils (first revision)
IS:4826-1979	Hot dipped galvanized coating on round steel wires (first revision)
IS:5317-2002	**Pitch mastic for bridge decking and Roads - specifications**
IS:5435-1987	General requirements for cold asphalt macadam mixing plants (first revision)
IS:5640-1970	Method for determining the aggregate impact value of soft coarse aggregate
IS:6006-1983	Uncoated stress relieved strands

Number Designation	Title
IS:6241-1971	Methods of test for determination of stripping value of road aggregates
IS:6909-1990	Supersulphated cement
IS:6925-1973	Methods of test for determination of water soluble chlorides in concrete admixtures
IS:7537-1974	Road traffic signals
IS:7623-1993	Specification for li thium base grease for industrial purposes (second revision)
IS:8041-1990	Rapid hardening Portland cement (second revision)
IS:8112-1989	43 grade ordinary Portland cement (first revision)
IS:8500-1991	Structural steel – microalloyed (medium and high strength qualities (first revision)
IS:8887-2004	**Bitumen emulsion for roads (cationic type) – specification (second revision)**
IS:9103-1999	Admixtures for concrete (first revision)
IS:9381-1979	Methods of testing tar and bituminous materials: determination of frass breaking point of bitumen
IS:9382-1979	Methods of testing tar and bituminous materials: determination of effect of heat and iar by thin film oven tests
IS:10262-2004	**Guidelines for concrete mix design**
IS:12269-1987	Specification for 53 grade ordinary Portland cement
IS:12330-1988	Specification for sulphate resisting Portland cement
IS:13321 (Part I)-1992	Glossary of terms for geosynthetics, part 1: terms used in materials and properties
IS:13325-1992	Determination of tensile properties of extruded polymer geogrids using the wide strip-test method
IS:13326 (Part I)-1992	Evaluation of interface friction between geosynthetics and soil-method of test, part 1: modified direct shear technique
IS:SP 23-1982	Handbook on concrete mixes
	(B) FOREIGN STANDARDS
ASTM D36 - 06	Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)

Number Designation	Title
ASTM D395 - 03(2008)	Standard Test Methods for Rubber Property—Compression Set
ASTM D412 - 06ae2	Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
ASTM D429 - 08	Standard Test Methods for Rubber Property—Adhesion to Rigid Substrates
ASTM D573 - 04	Standard Test Method for Rubber—Deterioration in an Air Oven
ASTM D624 - 00(2007)	Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers
ASTM D664 - 09	Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration
ASTM D797-82(1989)	Test Method for Rubber Property-Young's Modulus at Normal and Subnormal Temperatures (Withdrawn 1994) Withdrawn Standard:
ASTM D977 - 05	Standard Specification for Emulsified Asphalt
ASTM D979 - 01(2006)e1	Standard Practice for Sampling Bituminous Paving Mixtures
ASTM D1075 - 07	Standard Test Method for Effect of Water on Compressive Strength of Compacted Bituminous Mixtures
ASTM D1149 - 07	Standard Test Methods for Rubber Deterioration-Cracking in an Ozone Controlled Environment
ASTM D1559-89	Test Method for Resistance of Plastic Flow of Bituminous Mixtures Using Marshall Apparatus (Withdrawn 1998) Withdrawn Standard:
ASTM D2026 - 97(2004)	Standard Specification for Cutback Asphalt (Slow-Curing Type)
ASTM D2027 - 97(2004)	Standard Specification for Cutback Asphalt (Medium-Curing Type)
ASTM D2041 - 03a	Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
ASTM D2172 - 05	Standard Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures
ASTM D2240 - 05	Standard Test Method for Rubber Property—Durometer Hardness

Number Designation	Title
ASTM D2397 - 05	Standard Specification for Cationic Emulsified Asphalt
ASTM D3203 - 05	Standard Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
ASTM D3625 - 96(2005)	Standard Practice for Effect of Water on Bituminous-Coated Aggregate Using Boiling Water
ASTM D3910 - 07	Standard Practices for Design, Testing, and Construction of Slurry Seal
ASTM D4533 - 04	Standard Test Method for Trapezoid Tearing Strength of Geotextiles
ASTM D5976-96	Standard Specification for Type I Polymer Modified Asphalt Cement for Use in Pavement Construction –SUPERSEDED
ASTM E11 - 04	Standard Specification for Wire Cloth and Sieves for Testing Purposes
ASTM E810 - 03(2008)	Standard Test Method for Coefficient of Retroreflection of Retroreflective Sheeting Utilizing the Coplanar Geometry
AASHTO : T283-07-UL	Standard Method of Test for Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage, Single User Digital Publication
AASHTO : M294-08-UL	Standard Specification for Corrugated Polyethylene Pipe, 300- to 1500-mm Diameter, Single User Digital Publication
AASHTO :M288-06-UL	Standard Specification for Geotextile Specification for Highway Applications, Single User Digital Publication
AASHTO :M017-07-UL	Standard Specification for Mineral Filler for Bituminous Paving Mixtures
AASHTO : R005-08-UL	Standard Recommended Practice for Selection and Use of Emulsified Asphalts
AASHTO : M081-92-UL	Standard Specification for Cutback Asphalt (Rapid-Curing Type), Single User Digital Publication
AASHTO : M082-75	Standard Specification for Cut-back asphalt (Medium-curing type)
AASHTO : M140-03-UL	Standard Specification for Emulsified Asphalt
AASHTO : M57-80	Materials for embankments and subgrades
AASHTO : M147-65	Materials for aggregate and soil-aggregate sub-base, base and surface courses

Number Designation	Title
AASHTO : M216-05-UL	Standard Specification for Lime for Soil Stabilization, Single User Digital Publication
AASHTO : M249-08-UL	Standard Specification for White and Yellow Reflective Thermoplastic Striping Material (Solid Form), Single User Digital Publication
AASHTO : M268-08-UL	Standard Specification for Retroreflective Sheeting for Traffic Control
AASHTO : M282-99-UL	Standard Specification for Joint Sealants, Hot-Poured, Elastomeric-Type, for Portland Cement Concrete Pavements
AASHTO : M082-75-UL	Standard Specification for Cutback Asphalt (Medium-Curing Type), Single User Digital Publication
AASHTO : M140-03-UL	Standard Specification for Emulsified Asphalt
AASHTO : M208-01-UL	Standard Specification for Cationic Emulsified Asphalt, Single User Digital Publication
AASHTO : T182-84-UL	Standard Method of Test for Coating and Stripping of Bitumen-Aggregate Mixtures
AASHTO : T283-07-UL	Standard Method of Test for Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture-Induced Damage, Single User Digital Publication
BS : 410-2005	Test sieves – Technical requirements and Testing
Part 1	Test sieves of metal wire cloth
Part 2	Test sieves of perforated Metal plate
BS : 434	Bitumen road emulsions (anionic and cationic)
Part 2 : 1984	Specification for bitumen road emulsion
Part 2:2006	Code of practice for the use of cationic bitumen emulsions on roads and other paved areas
BS : 598	Sampling and examination of bituminous mixtures for roads and other paved areas
Part 104:1987	Methods of test for the determination of the density and compaction
Part 107:1990	Method of test for the determination of the composition of design wearing course rolled asphalt
BS : 729-1971	Hot dip galvanized coating on iron and steel articles

Number Designation	Title
BS : 812-1995	Testing aggregates
Part 2	Methods for determination of Density
Part 3-75	Methods for determination of mechanical properties
Part 111-90	Method for determination of ten per cent: fines value (TFV)
Part 114-1989	Method for determination of the polished-stone value
BS : 1047-1983	Specification for Air-cooled blast furnace-slag aggregate for use in construction
BS : 1154-2003	Natural rubber compounds – specifications
BS : 1377-1990	Methods of test for soils for civil engineering purposes
BS : 1447-1988	Mastic asphalt (limestone fine aggregates) for roads and footways and pavings in buildings
BS : 1449-1956	Steel plate, sheet and strip
Part 1-1991	Carbon steel plate, sheet and strip
Part 2-2008	Stainless and heat resisting plate, sheet and strip
BS : 1470-1987	Wrought aluminium and aluminium alloys for general engineering purposes – plate, sheet and strip
BS : 2000	Methods of test for petroleum and its products
Part 397:1995	Recovery of bitumen binders-dichloromethane extraction rotary film evaporator method – Withdrawn on 1.11.2007
BS : 2630-1982	Specification for resistance projection welding of uncoated low carbon steel sheet and strip using embossed projections
BS : 2870-1980	Rolled copper and copper alloys : sheet, strip and foil
BS : 3262	Hot-applied thermoplastic road marking materials
Part 1-1989	Specification for constituent materials and mixtures
Part 2-1999	Specification for road performance
Part 3-1989	Specification for application of material to road surface
BS : 5212:Part 2-1990	Code of practice for the application and use of joint sealants
BS : 6044-1987	Specification for pavement marking paints
BS : 6088-1981	Specification for solid glass beads for use with road marking compounds and for other industrial uses

Number Designation	Title
BS : 6906	Methods of test for geotextiles
Part 1-1987	Determination of tensile properties using a wide width strip
Part 2-1989	Determination of the apparent pore size distribution by dry sieving
Part 3-1989	Determination of water flow normal to the plane of the geotextile under a constant head
Part 4-1990	Determination of the puncture resistance 9CBR puncture test)
Part 7-1990	Determination of in-plane waterflow
BS : 7542-1992	Method of test curing compound for concrete
CRRI & IOC, New Delhi	Bituminous road construction handbook
BS : DD232-2006	Method for determination of the maximum binder content of bituminous mixtures without excessive binder drainage
MS-4 (7th edition)	The asphalt handbook (Asphalt Institute)
MS-2 (6th edition)	Mix design methods for asphalt concrete and other hot-mix types (Asphalt Institute)
MS-14 (3rd edition)	Asphalt Cold Mix Manual (Asphalt Institute)
GRI-GG1	Geogrid rib tensile strength (Geosynthetic Research Institute)
GRI-GG2	Geogrid junction strength (Geosynthetic Research Institute)
GRI-GG3	Tensile creep testing of geogrids (Geosynthetic Research Institute)